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Research Article

THE EVALUATION OF IRRIGATION EFFICIENCY OF SOLID SET SPRINKLER IRRIGATION SYSTEMS

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ABSTRACT
Evaluation is one of the components of every irrigation system to improve its management. Unfortunately due to lack of proper design and performance of the system in several agricultural lands, the efficiency of the Solid-set sprinkler irrigation systems is low or unacceptable. The specific objective of this study is to evaluate of irrigation efficiency of existing solid set or portable sprinkler irrigation systems under field conditions at Miandoab region. For this purpose, 10 solid set sprinkler irrigation systems were selected accidentally and were evaluated in three steps. Thus evaluating indicators were used such as Application Efficiency (AE) and Combined Efficiency (CE). The Wind Drift and Evaporation Losses (WDEL), Deep Percolation (DP) and overall average of losses were obtained 13.1, 14.0 and 27.1% respectively. The results showed that the overall average of system, application efficiency and combined efficiency were obtained 73.6 and 75.3% respectively. One of the main reasons for low application efficiency is existence of wind at area and lack of proper designing.

Keywords: *Application Efficiency and Combined Efficiency, Irrigation Systems, Sprinkler, Solid-Set and Water Losses*

INTRODUCTION
Efficient use of available water is essential because of a limited water supply and a serious drainage problem in a portion of the different regions. Irrigation efficiencies are directly related to the low water losses on the individual fields. In design and management of irrigation systems, efficient use of water is now often a major goal, as well as production of the crop. Of course, crop production is paramount to a grower who intends to stay in business, but he or she now looks also at water costs and farm sustainability as well as the potential for pollution of the resource by over irrigating. The main objective of irrigation is to apply the optimum amount of water to the crop root zone that the crop needs for development and also that cannot be provided by rains (Hamam *et al.,* 2003). One of the standard practices to characterize water use in an irrigated area is to conduct irrigation evaluations. In sprinkler irrigation, the most valuable outcome of evaluation process is irrigation efficiency. Irrigation efficiency defines how effectively an irrigation system supplies water to a given crop.

The first requirement for the efficient operation of an irrigation system is uniform water application. Pitts (2001) notes that a highly uniform water application does not ensure high efficiency since water can be uniformly under or over-applied. However, it is noted that a highly efficient system along with good crop yields requires uniform water applications (Griffiths and Lecler, 2001; Pitts, 2001). The measurement is generally made during once test and the determined value of CU becomes the basis for evaluating the system performance. A high uniformity is required to attain a satisfactory level of irrigation efficiency (Topak *et al.,* 2005).

An irrigation system evaluation involves taking in-field measurements and then using scientific and engineering principles to assess these measurements in the light of performance standards.

The goal of any sprinkler irrigation system is to apply the desired amount of irrigation water to the crop's root zone as efficiently and uniformly as possible. The factors that determine sprinkler performance characteristics include wetted diameter (swath radius), droplet size, which is a function of the operating pressure, the flow rate or discharge, the application rate, and uniformity of water application among others (Ahaneku, 2010).

Irrigation efficiency refers to the amount of water needed for crop production compared with the amount applied to the field and depends on system uniformity and management. It is defined as the ratio of the amount of irrigation water beneficially used to the amount of applied water. Beneficial use includes crop evapotranspiration, leaching for salinity control, frost protection, and cooling. The major losses which affect the irrigation efficiency are drainage below the root zone and surface runoff (Hanson, 2005).

As deep percolation increases, irrigation efficiency decreases. Therefore, when deep percolation amounts are the least, the calculated irrigation efficiencies are the highest.

Under low-to-moderate wind conditions, irrigations with well maintained sprinkler systems can produce good pre-irrigation efficiencies, since the water application rate is controlled by the irrigation system and not by soil characteristics. Well designed sprinkler systems must apply water at a rate that is less than the soil infiltration rate to minimize or eliminate runoff.

Solomon (1979), Dechmi *et al.*, (2003c) and Playa'n *et al.*, (2005) reported that wind is the most important natural factor affecting the performance of sprinkler systems. Dechmi *et al.*, (2003b) Expressed in many irrigation projects water use efficiency (WUE) is lower than expected value. Bavi *et al.*, (2009) reported that the water application efficiency in sprinkler irrigation systems before everything is controlled by the evaporation and wind losses.

MATERIALS AND METHODS

During the irrigation season in 2012 and 2013, 10 solid set sprinkler system catch can tests were conducted in 3 steps at 10 farmer's field (DL, OH, GP, DK, LO, FS, PH, GS, LA and KO) in the area of collective irrigation in Miandoab region, West Azarbaijan province at northwest of Iran in order to the evaluation of irrigation efficiency in solid set sprinkler systems. Miandoab region has a semi-arid climate, almost all set sprinkler systems used in the collective irrigation area are solid set and as most of the sprinklers have double nozzles, and this type was used in the experiments. All tests were carried out in the early morning under low wind conditions.

Wind drift and evaporation losses obtained from the following relationship:

$$WDEL = (1 - \frac{\overline{D}}{D_r}) \times 100 \qquad (1)$$

Where, $\overline{D}$, average of the water depth caught in catch cans *(mm)*.

D_r , average of the water depth of the flow rate in nozzle *(mm)*.

Also, Injection efficiency calculated by the following equation:

$$IE = \frac{\overline{D}}{D_r} \times 100 \qquad (2)$$

The percentage of deep percolation losses derived from the following equation:

$$DP = \frac{(\overline{D}_0 - SMD) \times \frac{N_1}{N}}{D_r} \times 100 \qquad (3)$$

Where, N_1 and $\overline{D}_0$ are the number and average of water in catch cans that water depth are greater than SMD, and N is the number of cans used in the evaluation.

The application and combined efficiency calculated by the following equations:

$$AE = (100 - WDEL - DP) \qquad (4)$$

$$E_C = \frac{(100 - DP)(100 - WDEL)}{100} \qquad (5)$$

The values of mentioned parameters were obtained from 10 solid set sprinkler systems in 3 evaluating steps. Data analysis was performed using the excel software.

RESULTS AND DISCUSSION

The values of Wind drift and evaporation losses and deep percolation losses were obtained from various evaluating steps (1, 2 and 3) at different solid set sprinkler systems are given in the Tables 1, 2 and 3 respectively.

Table 1: Values of percentage of Wind drift losses (WD) in various evaluating steps in different farmer's field sprinkler irrigation systems

Farmer's Field										
Step	DL	OH	GP	DK	LO	FS	PH	GS	LA	KO
1	9.7	2.5	5.9	6.2	2.8	7.7	0.4	10.0	4.7	5.4
2	2.3	4.9	4.9	4.2	2.8	5.0	5.4	7.7	11.0	8.7
3	0.0	13.1	6.0	1.0	1.9	2.0	8.9	15.2	6.9	5.1
Mean	**4.0**	**6.8**	**5.6**	**3.8**	**2.5**	**4.9**	**4.9**	**11.0**	**7.5**	**6.4**

Table 2: Values of percentage of evaporation losses(E) in various evaluating steps in different farmer's field sprinkler irrigation systems

Farmer's Field										
Step	DL	OH	GP	DK	LO	FS	PH	GS	LA	KO
1	5.9	6.4	3.2	5.9	7.8	0.5	7.1	5.3	5.6	4.8
2	8.3	7.2	6.3	8.3	9.8	6.5	7.8	4.8	4.2	6.4
3	13.2	9.1	7.2	14.9	10.2	8.2	10.2	8.9	7.2	10.1
Mean	**9.1**	**7.6**	**5.6**	**9.7**	**9.3**	**5.1**	**8.4**	**6.3**	**5.7**	**7.1**

Table 3: Values of deep percolation losses(DP) in various evaluating steps in different farmer's field sprinkler irrigation systems

Farmer's Field										
Step	DL	OH	GP	DK	LO	FS	PH	GS	LA	KO
1	15.3	7.8	19.1	10.2	19.3	12.3	8.3	22.2	10.5	15.2
2	16.1	9.2	13.2	16.3	17.5	13.2	6.2	16.8	12.8	12.1
3	13.4	1.0	33.1	11.5	18.2	14.6	8.4	20.2	15.6	11.3
Mean	**14.9**	**6.0**	**21.8**	**12.7**	**18.3**	**13.4**	**7.6**	**19.7**	**13.0**	**12.9**

The average of Wind drift losses was large, ranging from 2.5 to 11% with an average value of 5.6% (Table 1). The evaporation loss was large, ranging from 5.1 to 9.7% with an average value of 7.5% (Table 2). The average of Wind Drift and Evaporation Losses (WDEL) was obtained 13.1 ranging from 10.0 to 17.3 % in FS and GS irrigation systems respectively.

The deep percolation loss(DP) was ranged from 6.0to 21.8% with an average value of 14% (Table 3). The overall average of losses obtained 27.1%.

The results showed that when wind speed increase, wind drift losses increases and when temperature increase, evaporation losses increases.

The values of Injection, application and combined efficiency were obtained from various evaluating steps (1, 2 and 3) at different solid set sprinkler systems are given in the Tables 4, 5 and 6 respectively.

Table 4: Values of Injection efficiency in various evaluating steps in different farmer's field sprinkler irrigation systems

Farmer's Field										
Step	DL	OH	GP	DK	LO	FS	PH	GS	LA	KO
1	84.4	91.1	90.9	87.9	89.4	91.8	92.5	84.7	89.7	89.8
2	89.4	87.9	88.8	87.5	87.4	88.5	86.8	87.5	84.8	84.9
3	86.8	77.8	86.8	84.1	87.9	89.8	80.9	75.9	85.9	84.8
Mean	**86.9**	**85.6**	**88.8**	**86.5**	**88.2**	**90.0**	**86.7**	**82.7**	**86.8**	**86.5**

Table 5: Values of application efficiency in various evaluating steps in different farmer's field sprinkler irrigation systems

Farmer's Field										
Step	DL	OH	GP	DK	LO	FS	PH	GS	LA	KO
1	69.1	83.3	71.8	77.7	70.1	79.5	84.2	62.5	79.2	74.6
2	73.3	78.7	75.6	71.2	69.9	75.3	80.6	70.7	72.0	72.8
3	73.4	76.8	53.7	72.6	69.7	75.2	72.5	55.7	70.3	73.5
Mean	**71.9**	**79.6**	**67.0**	**73.8**	**69.9**	**76.7**	**79.1**	**63.0**	**73.8**	**73.6**

Table 6: Values of combined efficiency in various evaluating steps in different farmer's field sprinkler irrigation systems

Farmer's Field										
Step	DL	OH	GP	DK	LO	FS	PH	GS	LA	KO
1	71.5	84.0	73.5	78.9	72.1	80.5	84.8	65.9	80.3	76.1
2	75.0	79.8	77.1	73.2	72.1	76.8	81.4	72.8	73.9	74.6
3	75.2	77.0	58.1	74.4	71.9	76.7	74.1	60.6	72.5	75.2
Mean	**73.9**	**80.3**	**69.6**	**75.5**	**72.1**	**78.0**	**80.1**	**66.4**	**75.6**	**75.3**

The average of Injection efficiency was obtained 86.9% ranging from 82.7 to 90.0% in GS and FS irrigation systems respectively (Table 4).The average of application efficiency was obtained 73.6% ranging from 63.0 to 79.6% in GS and OH irrigation systems respectively (Table 5). The average of combined efficiency was obtained 75.3% ranging from 66.4 to 80.3% in GS and OH irrigation systems respectively (Table6).

The results showed that the overall average of system, application efficiency was obtained 73.6% that indicated the moderate efficiency. One of the main reasons for low application efficiency is existence of wind at area and lack of proper designing.

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