ASSESSMENT OF SPRINKLER IRRIGATION SYSTEMS OPERATION AT CHAHARMAHAL AND BAKHTIARI PROVINCE, IRAN

EVALUATION DE L'EXPLOITATION DES SYSTEMES D'IRRIGATION PAR ASPERSION DANS LES PROVINCES DE CHAHARMAHAL ET DE BAKHTIARI, IRAN

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ABSTRACT

Evaluation of different sprinkler irrigation systems is necessary to find any problem or shortcomings at the design, execution and management stages. Evaluation of a system means to assess the parameters such as irrigation efficiencies, water distribution coefficient and water adequacy at the field. Obviously, the higher magnitude of each of the above parameters alone is not sufficient to say a system operation is satisfied. This is because a system can be working very well when the peak water requirement is applied and high uniformity coefficient and efficiencies values are achieved but not so in other situations. Therefore, the objective of this research is to evaluate and compare the operation of different sprinkler irrigation systems such as conventional, wheel move and center pivot methods at Chaharmahal and Bakhtiari Province in Iran. For this purpose 3, 2 and 5 solid set, wheel move and center pivot methods were randomly selected. The evaluation results were statistically analyzed in an unequal complete randomized design. The analysis of variance showed that there was a significant difference among the water application efficiencies at the level of 95% and water adequacies values at the level of 99%. Based on this analysis, the results showed that the conventional sprinkler system has high evaluation parameters values including water application efficiencies and water adequacies as compared to wheel move and center pivot methods. Overall, this investigation indicated that the conventional sprinkler system has desirable parameters values on the existing climatic conditions at this province.

Key words: *Center pivot, conventional method, efficiency, evaluation, wheel move.*

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RESUME ET CONCLUSIONS

Le fonctionnement souhaitable des systèmes d'irrigation par aspersion peut rencontrer une difficulté dans la conception, l'exécution et la gestion des stades. Par onséquent, l'évaluation des systèmes d'irrigation par aspersion est obligatoire au stade 'exploitation. Évaluation d'un système comprend l'évaluation de l'efficacité des applications de l'eau, l'uniformité de distribution d'eau et d'irrigation adéquat oefficient coefficient d'une ferme. de grande valeur d'un paramètre d'évaluation unique ne suffit pas de dire un système qui fonctionne bien. En effet, un bon système de travail complet devrait inclure des valeurs élevées des paramètres d'évaluation tels que ainsi que l'eau d'irrigation de pointe exigence d'une ferme.

Ascough et Kiker (2002) réalisé série d'expériences sur la ferme de betterave sucrière de fonctionnement des différents systèmes d'irrigation par aspersion dans l'Afrique du Sud. Ils ont évalué les systèmes utilisant peu d'uniformité de distribution du quart (DU1 / 4) et les facteurs de l'efficacité de l'eau d'évaluation. Les résultats ont montré la DU1 / 4 des valeurs de 81,4, 60,9, 72,7, 67,4 et 56,9 pour cent et les valeurs de 83,6, 73,5, 67,7 et 78,9 pour cent respectivement pour pivot central, raingun, micro-irrigation, systèmes de gicleurs conventionnels et de disquettes. Mateo (2006) ont comparé trois systèmes d'irrigation, y compris sillon, goutte à goutte et saupoudrer de systèmes d'irrigation utilisant des facteurs de l'uniformité et l'application des coefficients de rendement. La réalisation des résultats souhaités des facteurs ci-dessus mentionnés évaluation a montré une bonne estimation de la performance réelle des systèmes d'irrigation goutte à goutte ou par aspersion sur le terrain, mais avec des productions de rendement différent, tandis que les paramètres d'évaluation n'a pas indiqué les valeurs souhaitables pour l'irrigation par rigoles. Ahaneku (2010) réalisé série d'expériences pour évaluer la performance d'un système de gicleurs portables neufs achetés par l'autorité inférieure du fleuve Niger le développement du bassin, Ilorin, Nigeria. Les résultats de l'évaluation sur le terrain a indiqué que le coefficient moyen d'uniformité (CU) et le ratio de performance de livraison (RMR) du système sont de 86% et 87%, respectivement, ce qui indique un rendement satisfaisant du système de gicleurs.

Mots clés : *Pivot central, méthode conventionnelle, efficience, évaluation, movement équipé de pneus.*

(Traduction française telle que fournie par les auteurs)

1. INTRODUCTION

Evaluation of a system means to assess the system performance for parameters such as irrigation efficiencies, water distribution coefficient and water adequacy at the field site. The higher magnitude of each of the above mentioned parameters alone is not sufficient to say a system operation is satisfied. This is because a system can be working very well when the peak water requirement is applied and high uniformity coefficient and efficiencies values are achieved but not so in other situations.

Evaluation of a system performance is obligatory at each field repeated for two or three times per year to find weather it works well. Although, many investigations about systems evaluation have been done so far over the world, but due to variety of climates, soil types, types of plants and characteristics of systems, the results of investigation can not be generalized to other part of the world. For example, Ahaneku (2010) evaluated portable irrigation systems in Nigeria and reported 86% and 87% values for water distribution uniformity coefficient and water application efficiency and then he recommended using this system to irrigate agricultural lands is desirable. Hill (2002) compared sprinkler irrigation systems performance with surface irrigation system in Utah State. He represented water application efficiencies 70% and 50% for sprinkler and surface irrigations. From the 0.53 million hectares of agricultural lands in Utah State, more than 40% are irrigated by sprinkler irrigations methods. The most adapted sprinkler irrigation system is semi-solid set systems, wheel move and center pivot

Ascough and Kiker (2002) performed series of experiments on the sugar beet farm operating different sprinkler irrigation systems in the South Africa. They evaluated the systems using low quarter distribution uniformity ($DU_{1/4}$) and water efficiency evaluation factors. The results showed the $DU_{1/4}$ values of 81.4, 60.9, 72.7, 67.4 and 56.9 percent and the values of 83.6, 73.5, 67.7 and 78.9 percent respectively for center pivot, rain gun, micro-irrigation, conventional and floppy sprinkler systems. Mateo (2006) compared three irrigation systems including furrow, drip and sprinkle irrigation systems using uniformity coefficient and application efficiency factors. Achievement of desirable results of the above mentioned evaluation factors showed a good estimate of actual performance of drip and sprinkler irrigation systems on the field, but with different yield productions, while the evaluation parameters did not indicated desirable values for furrow irrigation.

2. MATERIALS AND METHODS

Shahrekord Township with the area of 3692 km^2 is located in the northeast of Chaharmahal and Bakhtiari Province at the longitude of 49^o, 22' to 50^o, 49' and latitude of 32^o, 20' to 33^o, 31'. Its mean rainfall depth is 319 mm, its dominant southwestern wind average velocity is 4.1 m/s and the mean annual temperature is 11.5 degrees, July is the warmest and January is the coldest months of year and the corresponded mean annual relative humidity is 46%, as reported by Chaharmahal and Bakhtiari Meteorological administration (1389).

The main objective of this study was to evaluate the operation of conventional, wheel move and center pivot sprinkler irrigation systems at Shahrekord Township, Iran. For this purpose three, five and two farms respectively under wheel move, fixed conventional and center pivot sprinkler irrigation systems were randomly chosen to assess the operating parameters of systems. The number selected for each system depends upon the existing situation. This is because the conventional systems are the most attitude systems for local farmers and there are just three wheel moves and two center pivots systems operating in this region. The characteristics of selected systems are represented in the Table 1.

Table 1. General characteristics of fields and systems under evaluation (Caractéristiques générales des champs et des systèmes en cours d'évaluation)

No	Field	Production	Area (m^2)	Systems	Location	Field
1	*GV1-1	Cubage	11	Wheel move	Farrokhshahr	Goldareh-1-1
2	*GV1-2	Alfalfa	11	Wheel move	Farrokhshahr	Goldareh-1-2
3	GV2	Canola	12	Wheel move	Farrokhshahr	Goldareh-2
4	GS	Alfalfa	100	Conventional	Farrokhshahr	Goldareh-3
5	PS	Alfalfa	15	Conventional	Shahrekord	Pourman
6	AS	Canola	60	Conventional	Ben	Aflaki
7	ES	Potato	25	Conventional	Shalamzar	Abraham
8	SS	Potato	83	Conventional	Chalshotor	Safarpour
9	SC	Alfalfa	22	Center pivot	Chalshotor	Chalshotor
10	GC	Sugar beet	25	Center pivot	Gahrou	Gahrou

* Two laterals of centre pivot

The soil, operating system, climate and water characteristics of the selected farms were measured directly on the farm or in the laboratory. For instances, Soil texture and particle distribution were determined using sieve analysis procedure. Soil apparent specific gravity and soil moisture content were also measured taking soil samples from the depths 0 to 40 cm in the field. Field capacity, permanent wilting point and infiltration rates were determined both in the field and referring to the texts. Rainfall simulator method was adapted to measure soil infiltration under sprinkler irrigation conditions (Table 2). Climate parameters such as temperature, depth of rainfall and evaporation data were taken from the closest synoptic stations. No limitation was observed in the quality of water resources used to irrigate lands. The characteristics of systems such as laterals and sprinklers distances, flow rates, systems pressure and distance of throw wtere determined in the field (Tables 3 and 4). Catch can method was also used to determine water application depth in the field.

Table 2. Soil characteristics for tests (Les caractéristiques du sol pour les essais)

Field	Initial moisture* (%)	Basic infiltration (mm/hr)	MAD (%)	F.C.* (%)	Bulk density (gr/cm^3)	Texture
GV1-1	16.46	13	30	19.36	1.30	Clay loam
GV1-2	18.5	13	65	19.36	1.25	Clay loam
GV2	13.82	13	65	19.36	1.25	Clay loam
GS	7.30	13	65	17	1.25	Clay loam
PS	10.6	15	65	18.15	1.20	loam
AS	13.5	13	65	20.2	1.20	Clay loam
ES	15	13	30	20.97	1.20	Clay loam
SS	17.9	11	30	19.63	1.20	Silty clay loam
SC	10.6	11	65	19.70	1.25	Silty clay loam
GC	14.2	13	65	19.04	1.20	Clay loam

* by weight, MAD = maximum allowable deficit, F.C. = field capacity

Table 3. Some of the mean characteristics of systems at the time of assessment (Certaines des caractéristiques moyennes des systèmes au moment de l'évaluation)

Field	Application rate (mm/h)	Wetting diameter (m)	Discharge (lit/s)	Pressure (m)	[1]S_l × [2]S_m (m×m)
GV1-1	11.6	30	0.69	23.30	18×12
GV1-2	11.5	28	0.69	23	18×12
GV2	8.5	24	0.51	25.3	12×18
GS	9.4	20.7	1.59	22.5	23×27
AS	15.7	44	2.70	46	25×25
SS	18.1	37.3	3.10	31.30	25×25
ES	16	37.3	2.73	41	25×25
PS	15.5	50	2.70	35	24×26
SC	2.3	8	0.85	6	----
GC	3	7	1	7	-----

Table 4. Some of the mean characteristics of center pivot systems at the time of assessment (Certaines des caractéristiques moyennes des systèmes à pivot central au moment de l'évaluation)

Field	First sprinkler distance of throw (m)	Last sprinkler distance of throw (m)	Span length (m)	No of sprinkler per span	No of spans	Lateral length (m)	System speed (hr/r)	Speed of last tower (m/hr)
SC	3	8	47	16	5	265	22.3	75.7
GC	3	7	53	15	6	282	32.5	54.5

In a full irrigation system assessment the main parameters are: water distribution uniformity, water application rate and water adequacy. The following formulae were used to predict these parameters:

$$E_a = \frac{D_a}{D_r} \times 100 \quad (1)$$

$$AELQ = \frac{D_q}{D_r} \times 100 \quad (2)$$

$$PELQ = \frac{SMD}{D_r} \times 100 \quad (3)$$

$$Cu = \left[1 - \frac{\sum_{i=1}^{n} \left| D_i - D \right|}{D \times n} \right] \times 100 \quad (4)$$

$$DU = \frac{D_q}{D_a} \times 100 \quad (5)$$

$$L_s = \left[1.98 D^{-0.72} + 0.22 \left(e_s - e_a \right)^{0.63} + 3.6 \times 10^{-4} h^{1.16} + 0.14 U^{0.7} \right]^{4.2} \quad (6)$$

$$e_s - e_a = 0.61 \exp \left[17.27T / \left(T + 237.3 \right) \right] \left(1 - RH \right) \quad (7)$$

$$DP = \frac{D_r (1 - L_s / 100) - SMD}{D_r} \times 100 \quad (8)$$

$$SMD = \left(\theta_{FC} - \theta_i \right) \times r \quad (9)$$

In which, E_a = application efficiency, D_a = mean water application depth, D_r = mean water depth measured at nozzles, AELQ = low quarter actual water application efficiency, PELQ = low quarter potential water application efficiency (Benami,1984), D_q = low quarter water application depth, SMD = soil moisture deficit, D_i = water application depth at point i, D = Mean water depth, n = the number of points, CU = uniformity coefficient (Christiansen, 1942), DU = distribution of uniformity, L_s = evaporation and wind drift losses, e_s - e_a = vapor pressure deficit, RH = Relative humidity, DP = deepercolation, θ_{fc} = soil moisture content at field capacity, θ_i = initial soil moisture content, r = effective root depth.

3. DISCUSSION

As shown in the Table 2, the values of basic infiltration rates are smaller than 15 mm/hr; therefore, the peak application rates of the systems should be equal or less than this value to have no runoff during the irrigation time. Accordingly, the majority of systems were correctly designed and no runoff was observed from the corresponding fields, except SS field. As reported earlier, the dominant winds direction in the region was from southwestern to northeastern. As a rule the laterals layout of all systems should be perpendicular to the wind direction, except center pivot lateral which is always circulating and changing, Field examinations showed that this rule was considered in the fields PS, SS and GS and failed in others.

The results of evaluation parameters were statistically analyzed using a completely randomized design with unequal numbers of repetitions with three treatments (wheel move, solid set and center pivot systems) and three replications for each farm (test) and 29 for all. The analysis of variance of evaluation parameters showed significant differences among water application efficiencies and water adequacy coefficients of above mentioned systems at the level of 95 and 99 percent respectively and no significant meaning among the other parameters (Table 5). Based on this analysis, the fixed conventional system had higher values of water application efficiency and irrigation adequacy than wheel move and center pivot systems. This is why this system was dominantly adapted and used by the farmers over the region.

Table 5. Analysis of variance of wheel move, center pivot and conventional systems performance (Analyse de variance de déplacer la roue, pivot central et la performance des systèmes classiques)

		Application efficiency (AE)			Irrigation adequacy		
SC[1]	Df[2]	SS	MS	F_s	SS	MS	F_s
Treatments	2	1042.9	521.4	4.03*	20411	10206	8.21**
Error	26	2361.3	129.3		21942	1229	
Total	28	4404.2			52353		

1- Sources of changes, 2- Degree of freedom

Summary of mean evaluation parameters are depicted in Table 6. As per the result of this research, center pivot systems had a higher application and potential efficiencies than others, but its water adequacy was the least. This means that nowhere in the field received water was equal to or more than the required irrigation depth. Therefore the yield production qualitatively and quantitatively reduced. Field investigation showed that if machine speed was correctly selected, center pivot system was the most efficient system which was approved by other researchers (Ascough and Kiker, 2002). However, the maintenance and performance of this system is a big problem. This is because this system needs high expertised worker. Table 6 also shows that the wheel move systems had the lowest evaluation parameters values including troubles in changing system position in the field, time lost and no adapted to some productions.

Table 6. Summary of evaluation parameters results related to three sprinkler irrigation systems (Résumé des résultats des paramètres d'évaluation connexes à trois systèmes d'irrigation par)

System	IA[1]	[2]$DU_{1/4}$(%)	[3]CU(%)	[4]PELQ(%)	[5]AE(%)	Field
Wheel move	90.27	61.5	72.9	42	65.1	GV1-1
	70.2	60.4	72.6	42.9	62.4	GV1-2
	41.7	55.1	66.9	46.1	76.7	GV2
	67.4	59	71.1	44	68.1	Mean
Conventional	45.7	57.8	67.1	50.7	82.2	GS
	100	78.2	79	60.4	86.1	PS
	86	78	87.9	69.9	88	AS
	55.2	65.1	75.4	55	80.2	ES
	71	69.7	78.6	47	61.2	SS
	71.8	69.8	77.6	55.6	79.6	Mean
Center pivot	0	68.2	81	64	92.6	SC
	0	64.4	78.6	55.2	85.5	GC
	0	66.3	79.8	59.6	89.6	Mean
	46.4	65	76.1	53.1	79.1	Total Mean

1- irrigation adequacy, 2-low quarter distribution uniformity, 3- uniformity coefficient, 4- potential low quarter uniformity, 5-application efficiency

4. CONCLUSIONS

The following results drawn from this investigation:

Among the irrigation systems performance at Chahamahal and Bakhtiari Province, the conventional irrigation systems evaluation parameters such as application efficiency, low quarter water potential efficiency, water adequacy and water uniformity coefficient had the highest magnitudes than others followed by wheel move systems. The center pivot systems showed zero water adequacy, this is due to no where on the field surface received water depth equal to or more than water requirement depth. Among the fields under examination tests, the AS field had the highest values of evaluation parameters as compared to the other.

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