ON FIELD ASSESSMENT OF TRADITIONAL MANAGEMENT EFFICIENCY IN BORDER IRRIGATION SYSTEM IN LORESTAN PROVINCE, WEST OF IRAN

EVALUATION A LA PARCELLE DE L'EFFICIENCE DE GESTION TRADITIONNELLE DU SYSTEME D'IRRIGATION PAR PLANCHES DANS LA PROVINCE DU LORESTAN A L'OUEST DE L'IRAN

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ABSTRACT

Irrigation efficiency reflects how good or bad the water resources are being used for irrigation. Traditional border irrigation system is prevalent system in about 80% of irrigated lands in west areas of Iran. A study was conducted to evaluate the present management efficacy of border irrigation system across the field in 16 wheat, sugar beet, alfalfa, and bean farms in Lorestan province, and west of Iran. Results indicated that in most cases deficit irrigation were used. This increased water application and storage efficiencies, but in most cases, irrigation sufficiency were not achieved. This is resulted from imbalance between system fractions and depletion in initial soil moisture. Range of application efficiency, storage efficiency, deficit/excess efficiency, deep percolation, tail water efficiencies in the farms under experiment, was measured from 10.5 to 95.5, 21.6 to 100, 9.3 to 100, 0.6 to 83.5 and 0 to 42.9 per cent, respectively. Uniformity of water distribution indices were low and caused huge water loses (about 30-60% of the water that entered the border) occurred by deep percolation, especially along the first half of border length. Lack of farmers' knowledge about soil moisture condition and accurate irrigation time, traditional system layout, weak irrigation scheduling as well as imbalance between irrigation system properties lead to water losses and reduced irrigation efficiency. Practical solutions to enhance irrigation management efficiency are to adjust geometric features of border based on amount of water entrance, regulate cut-off time as well as to determine appropriate irrigation time based on pre-irrigation soil moisture.

Key words: *Assessment, Irrigation Efficiency, Irrigation Management, Border Irrigation.*

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RÉSUMÉ ET CONCLUSIONS

Conditions tirant d'eau, la pénurie d'eau et inapproprié technique et propriétés géométriques système d'irrigation en particulier dans un état semi-arides du pays, a créé une nécessité à l'efficacité du système d'irrigation évalués. Cette évaluation peut aider les gestionnaires de l'eau locale pour distinguer les avantages et inconvénients du système d'irrigation les plus répandues (irrigation des frontières) dans ce domaine. Système d'irrigation traditionnel frontière est réalisée dans environ 80% des terres irriguées dans les régions ouest de l'Iran. Efficacité de l'irrigation dans cet état est estimé à environ 35%. Il n'y a pas d'information sur la cause principale et les chemins de la perte d'eau. On estime qu'environ les deux tiers de l'eau perdue est échappé dans le champ par percolation profonde, eau, etc queue Cette étude a été menée pour évaluer l'efficacité de la gestion actuelle du système d'irrigation des frontières à travers le champ de blé en 16, la betterave à sucre, la luzerne, fermes de haricots et de la province du Lorestan, une région semi-aride dans l'ouest de l'Iran. L'état d'avancement de l'efficacité d'irrigation, l'irrigation déficitaire, principales voies de la perte d'eau dans les fermes expérimentales ont été quantifiées par différents indices d'efficacité et une analyse appropriée.

La relation entre le déficit d'humidité admissible, le déficit d'humidité du sol avant l'irrigation et la profondeur infiltré a indiqué que dans l'irrigation les plus déficit cas ou l'irrigation et le stress ont été réalisés. Cela est dû à augmenter la demande en eau et de l'efficacité de stockage, mais dans la plupart des cas, la suffisance d'irrigation n'a pas été faite. Ceci est résulté un déséquilibre entre les fractions du système et l'appauvrissement de l'humidité du sol initial. Domaine d'application de l'eau, l'efficacité du stockage, le déficit / excédent d'efficacité, la percolation profonde, d'économie d'eau de queue dans les exploitations en cours d'expérimentation, a été mesurée de 10.5 à 95.5, 21.6 à 100, de 9.3 à 100, de 0.6 à 83.5 et 42.9 pour cent à zéro, par conséquent.

Irrigation courbes impliqué les effets de l'humidité initiale du sol, la pente et les dimensions des frontières sur les flux d'entrée et l'uniformité de distribution de l'eau. Uniformité des indices de distribution d'eau étaient faibles et causé d'énormes perd de l'eau (environ 30-60% de l'eau est entrée dans la zone frontalière) par percolation profonde en particulier le long de la première moitié de la longueur de la frontière. En dépit des énormes quantités d'eau à faible perte indices efficacité de l'irrigation, la plupart des cultures ont été sous la contrainte de l'eau et la carence d'irrigation.

Les résultats indiquent que le système traditionnel de gestion de l'irrigation était inefficace et avait plus d'inconvénients. Le manque de connaissances des agriculteurs sur l'état d'humidité des sols et l'irrigation heure exacte, les terres traditionnelles et le système propriétaire des ressources en eau, des calendriers d'irrigation faibles ainsi que le déséquilibre entre les propriétés du système d'irrigation entraînent des pertes d'eau et efficience de l'irrigation réduite.

Mots clés : *Evaluation, efficience en irrigation, gestion d'irrigation, irrigation par planches.*

(Traduction française telle que fournie par les auteurs)

1. INTRODUCTION

The main limitation of production in Iran is the shortage of water resources that requires improved irrigation management and maximum use of limited water resources. Irrigation efficiency is a measure of irrigation performance in terms of the water required to irrigate a field, farm, basin, irrigation district, or an entire irrigated area. It helps evaluating irrigation water use and to promote better or improved use of water resources, particularly those used in agriculture and turf/landscape management (Horrigan 2009).

Various indices have defined and applied for determining irrigation efficiency and uniformity (Lankford 2006 and Howell 2003). Irrigation efficiency evaluation could be useful to distinguish advantages and disadvantages of the current system. An irrigation system with optimized efficiency will improve all the quantitative and qualitative output due to irrigation (Rodriguez et al 2004). Irrigation efficiency is defined in terms of: 1) the irrigation system Performance, 2) the uniformity of the water application, and 3) the response of the crop to irrigation (Howell 2003). Uniformity of water distribution across the field, especially in border irrigation, plays a key role in irrigation efficiency enhancement. Uniformity depends on method of irrigation, land topography, soil type and soil hydraulic characteristics (Kang et al. 2009). In border irrigation system, this uniformity is depended on border geometric dimensions and flux of water to the border area (Kang et al 2009).

Studies on irrigation efficiency show that it is low in Iran as compared to the world average values (Sepaskhah and Ghahraman 2004, Abbasi 2000). Moayeri and Kaveh (2009) determined irrigation efficiency between 25.8-63.5%. This study was conducted to evaluate the present management efficacy of border irrigation system across the field in 16 wheat, sugar beet, alfalfa, and bean farms in Lorestan province, a semi arid region in the west of Iran. In this study irrigation efficacy, deficit irrigation, and main water loss paths in the experimental farms were quantified by different efficiency indices and appropriate analysis.

2. MATERIALS AND METHODS

Sixteen border-irrigated farms were selected in different parts of Lorestan province, west of Iran. These farms have representative conditions in physical and geometric properties, cropping system and management diagnosis for different regions of this province. The studied farms included five wheat, four bean, four alfalfa and three sugar beet at different growth stages. Border geometric properties were determined (Table 1). Disturbed and undisturbed soil sampling in different depth (0-20, 20-40, and 40- 60 cm) was done before irrigation for determining gravimetric soil moisture and measuring some soil properties including soil texture, soil organic matter and bulk density in the root development zone.

Table 1. Geometric properties and some soil diagnosis of experimental borders (Propriétés géométriques et d'un diagnostic des sols des frontières expérimentale)

Infiltration rate mm/h	Texture	Bulk density (g/cm^3)	Slope (%)	Border width (m)	Border length (m)	Region	Growth stage	Crop type	No.
60	Si.C	1.1	1.8	7.3	92	Chaghalvandi	Stem stage	wheat	1
62	Si.C	1.08	1.2	11.1	185	Aleshter	flowering	wheat	2
67	Si.C	1.25	1.8	6.1	84	Chaghalvandi	flowering	wheat	3
220	C.L.	1.19	1.35	6.6	110	Aleshter	dough	wheat	4
180	Clay	1.15	1.19	19.6	136	Chaghalvandi	dough	wheat	5
70	Si.C	1.16	1.32	4.9	45	Aleshter	Germination	Alfalfa	6
152	C.L.	1.32	1.45	11	150	Aleshter	First harvest	Alfalfa	7
71	Si.C	1.2	1.8	5	100	Khorram abad	flowering	Alfalfa	8
75	C.L	1.31	1.8	15	80	Khorram abad	Third harvest	Alfalfa	15
110	L.S	1.5	2.2	7.5	200	Dorood	4-6 leaf stage	Sugar beet	10
89	Clay	1.25	1.38	6	268	Dorood	6-8 " "	Sugar beet	11
60	Clay	1.05	0.9	12.5	100	Aleshter	8-10 " "	Sugar beet	13
---	Clay	1.05	2	6	313	Aleshter	Initial flowering	bean	9
108	Si.C.L	1.35	2	5	73	Dorood	flowering	bean	12
---	Clay	1.22	1.17	5/6	190	Aleshter	podding stage	bean	14
69	Clay	1.15	1.9	5	90	Firooz abad	Pod filling	bean	16

Irrigation time was recorded and the water inflow-outflow was measured by flume. Soil moisture content was determined gravimetrically before and 24 to 48 hours after irrigation for the root zone. The depth of stored water in the soil was determined using Eq. 1:

$$D = \frac{[(Pm_2 - Pm_1) \times Bd] \times d}{100} \qquad (1)$$

Where D: depth of stored water after irrigation (cm), Pm_1: Mean gravimetric soil moisture content in root development depth after irrigation (cm), Pm_2: Mean gravimetric soil moisture content in root development depth before irrigation (cm) and d: depth of root development depth.

Undisturbed soil samples were collected across borders by core sampler for measuring soil bulk density in each soil horizon and in each sampling station. Water flow e, recession and infiltration time were measured by dividing the borders in equal distances and marking with wooden pegs.

Using the collected information, different efficiency indices including application efficiency, storage efficiency, deficit/excess efficiency, tail water ratio and deep percolation ratio were calculated. Uniformity indices including and Christiansen coefficient of uniformity and uniformity of distribution also determined. Efficiency and uniformity indices was measured by the equations 2-8.

$$Ea = \frac{V_s}{Vt} \times 100 \quad (2)$$

$$Es = \frac{V_s}{V_{rz}} \times 100 \quad (3)$$

$$E(d/e) = \frac{V_s}{(V_t - V_d)} \times 100 \quad (4)$$

$$TWR = \frac{V_{TW}}{Vt} \times 100 \quad (5)$$

$$DPR = \frac{V_{DP}}{Vt} \times 100 \quad (6)$$

$$Dua = \frac{d_{min}}{\bar{d}} \times 100 \quad (7)$$

$$Cu = \left[1 - \frac{\sum_{i=1}^{n} \left| \left(di - \bar{d} \right) \right|}{n\bar{d}} \right] \quad (8)$$

Where:

E_a: the application efficiency (percentage),

V_s: the irrigation water stored in the root depth (m^3),

V_t: the water delivered to the border (m^3),

E_s: the storage efficiency (percentage),

V_{rz}: capacity storage of root zone (m^3),

V_d: volumetric water deficit in the root depth after irrigation (m^3),

V_{tw}: the water was tailed or runoff from border (m^3),

V_{Dp}: volume of deep percolated water (m^3);

The general form of the distribution uniformity can give as distribution uniformity or Du_p (percentage), C_U: the Christiansen's uniformity coefficient (percentage), n: the station numbers, d_i: depth of infiltrated water in each station (mm), d_{min} minimum depth of infiltrated water along the border, $\bar{d}$: average depth of infiltrated water along the border.

Moisture allowable deficit (MAD) content in the root depth in each irrigation and border measured by touching method based on apparent condition of the soil and soil texture. Soil moisture deficit before irrigation (SMD) (as an indicator of deficit irrigation) in the root depth determined considering crop type and growth stage.

3. RESULTS AND DISCUSSION

Comparison among infiltrated depth (d) and SMD indicated that deficit irrigation and water stress has occurred in the 82% of farms so that, only one half of SMD was attained in one quarter of fields (Fig. 1). SMD, MAD and d indices indicated that the borders containing bean crop did not encounter water stress and deficit irrigation did not occur. However, the other farms encountered to water stress (Fig. 2). Depth of used water in each border was dependent to border dimensions and input water flow. Amount of MAD was dominantly dependent of the crop type, and growth stage.

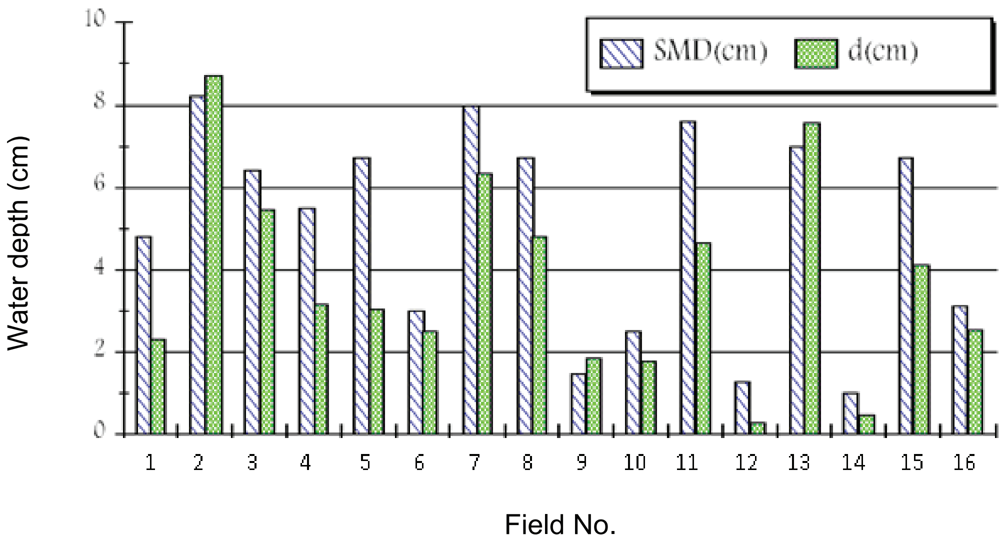

Fig. 1. Comparison of soil moisture deficit (SMD) and depth of irrigation water (d) among experimental fields (Comparaison du déficit d'humidité du sol (SMD) et la profondeur de l'eau d'irrigation (d) entre les champs d'expérimentation).

Results from measuring MAD and SMD (Fig. 2) indicated that in wheat farms water stressed and deficit irrigation was dominant. For example in the field no. 2, MAD was about half of SMD. This trend existed in the alfalfa and sugar beet farms with more intensity but in borders with bean crop SMD was less than moisture allowable deficit for this crop. Therefore, this trend increased application efficiency in wheat, sugar beet and alfalfa and decreased in bean fields (Table 2).

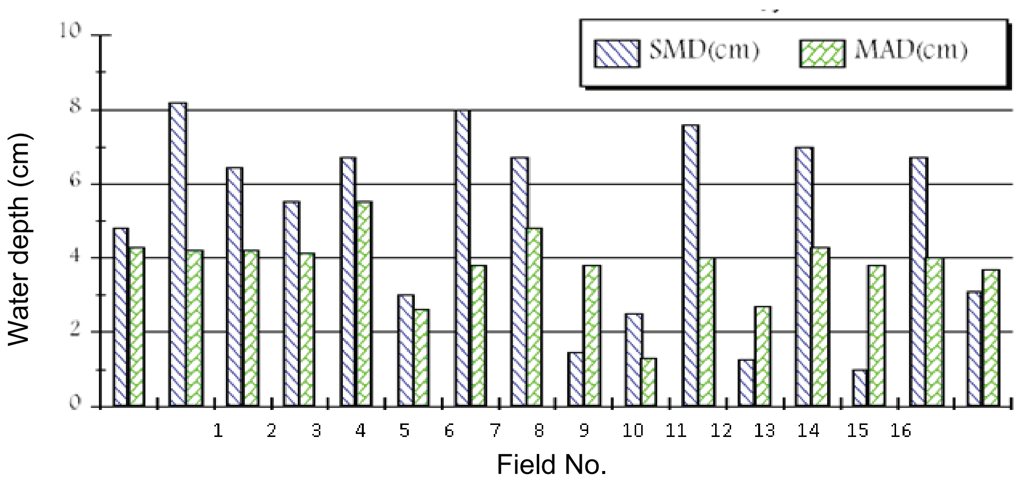

Fig. 2. Comparison of soil moisture deficit (SMD) and Moisture allowable deficit (MAD) among experimental fields fields (Comparaison du déficit d'humidité du sol (SMD) et de l'humidité du déficit autorisé (MAD) parmi les champs d'expérimentation)

The lowest value of $E_{d/e}$ was for the bean borders where MAD was higher than SMD. On the other hand, the maximum $E_{d/e}$ was in the sugar beet borders. For example field No. 13 with 100*12.5 m dimensions and slope=0.9% has $E_{d/e}$ = 100%. In the borders with higher $E_{d/e}$ there were approximately equal SMD and d values (Table 2). This phenomenon indicated that irrigation sufficiency was at desirable status (Skaggs and Samani 2005).

Table 2. Results of different irrigation efficiency and uniformity indices (Résultats d'efficacité d'irrigation et de différents indices d'uniformité)

No.	TWR (%)	DPR (%)	E_s (%)	E_a (%)	DU_a (%)	Cu	$E_{d/e}$(%)
1	5.7	58.7	56.4	35.5	83	0.912	27.5
2	3.4	24.7	100	71.8	83.6	---	71.8
3	9.2	15	85	75.8	71.6	0.823	66.8
4	4.7	3.3	57.6	92	67.5	0.918	54.9
5	5.7	79	45	15.6	23.7	0.623	5/10
6	1.8	57	83.7	40.8	58.6	---	38.1
7	0	19.2	79.2	64.7	52.5	0.653	64.8
8	4.8	30.3	71.6	65.1	86	0.814	52.8
9	0	35.8	100	64.2	75.7	---	---
10	13.4	36.8	70.4	49.8	10	0.927	33
11	0	75.1	61	24.5	63.1	0.610	19.7
12	0	83.5	21.6	16.5	98	0.973	10.3
13	3.9	0.6	100	95.5	89.1	0.829	100
14	7.5	82	45	10.5	90	---	9.3
15	0	34.4	61.2	65.6	97.5	0.976	46.3
16	42.9	8.2	81.6	48.9	58.1	0.966	43.1

Assessing the amounts of TWR indicated the lower value of tail water in most borders. Values of this indicator depend of the border dimensions, amount and flow of entered water, soil moisture before irrigation as well as crop type (Boss 1979; Heerman et al. 2007). In the field no. 10 and 16, because of higher border slope, lower SMD as well low length and width, amounts of TWR raised (Table 2). For preventing that, border length and or irrigation interval must increase.

DPR index results (Table 2) showed that the most significant part of the used water drained in the first half of the borders as deep percolation out of the reach of plant roots. In 40% of farms more than half of water was wasted by this way (Table 2). Lankford (2006) said that to avoid this, the better acquainted with the principles of system design and with proper regard to soil properties, geometry and crop type, while choosing the appropriate border dimensions, we apply the fit input water. Also by the timing right, we must schedule the time of irrigation to minimize casualties. The higher is the differences between MAD and SMD, the higher will be DPR and loss of water by deep percolation.

Obviously, any factor influencing irrigation uniformity can decrease DPR in the irrigation timing right. Maximum DPR belonged to the field No. 12 and 14 that up to 80% of applied water was lost by deep percolation. There were reasons that SMD was very lower than MAD and length of the border was very long. In alfalfa fields on average one third of the water used in this way and in the first half the border length were been outside of roots accessibility. Sinai and Jain (2005) reported that irrigation scheduling and appropriate irrigation timing determining decreased DPR in about 5%.

Results from E_a indicated that its range varied from about 15.6 – 95.5% (Table 2). Abbasi et al. (2000) reported that the range of application efficiency in border irrigation was about 17.8-69.7% in north of Iran. Minimum E_a was in border No.5. The main reason was long border length and high SMD that decreased irrigation uniformity indices and increased DPR to about 80%. Higher value of E_a should be an indicator of increasing water storage in root zone depth. Also, whenever plants encountered deficit irrigation and water stress and border size is selected to suit the input water flow, the value of this E_a will be higher (Gupta et al. 2009).

Range of E_s was in 21.6-100% among the experimental borders. Findings from E_s shown in Table 2 indicated that in the majority of the cases up to one-half of needed water used to achieve field capacity in root depth. However, water losses in the same fields were high as deep percolation and runoff. This is an indicator of insufficient irrigation. Results from Parvizi (2005) research indicated that enhanced irrigation uniformity caused homogenized infiltration time across the borders and finally soil moisture distribution uniformed along the profile and root depth. Therefore, application and storage efficiencies will promote.

Uniformity indices including DU_a and C_U amounts were ranged about 10-98% and 0.61-0.976, respectively. Comparison between the values of application efficiency with Cu and Dua, showed that there is no compliance between current geometrical and irrigation management system components and specifications that must be considered in designing this system. Sepaskhah and Ghahraman (2004) indicated that by volumetric and alternative delivery of irrigation and irrigation in the night time, irrigation uniformity and application efficiency can improve. Based on evaluation of the above efficiency indices and crop type the following points emerge:

1. Use of border irrigation systems in sugar beet has a good efficiency. Therefore, by proper design of system and selection of appropriate border dimensions, system disadvantages can overcome.

2. Bean irrigation always done by short interval and regardless of soil moisture status. It recommends depth of irrigation water decrease in this crop.

3. Practical ways to improve efficiency indices is to set the value of cross-flow inlet regulation, border length, location and time interval since the water cut to the border and well informed of the status of soil moisture before irrigation.

4. Concepts such as amount of water requirements in different growth stages, soil moisture conditions, proper irrigation planning, and proper timing of irrigation extend and educate to the farmers.

4. CONCLUSIONS

Draught conditions, water scarcity and inappropriate technical and geometric irrigation system properties especially in semi-arid condition of the country, created a necessity to evaluated irrigation system efficiency. Traditional border irrigation system is performing over about 80% of irrigated lands in west areas of Iran. Irrigation efficiency in this condition has been estimated as about 35%. There are no information on the main causes and paths in water loss. It is estimated that about two third of the water loss is due to deep percolation, tail water etc. This study was conducted to evaluate the present management efficacy of border irrigation system across 16 wheat, sugar beet, alfalfa, and bean farms in Lorestan province, a semi arid region in the west of Iran. The status of irrigation efficacy, deficit irrigation, and main water loss paths in the experimental farms by different efficiency indices and appropriate analysis were quantified.

The relationship between moisture allowable deficit (MAD), soil moisture deficit before irrigation (SMD) and infiltrated depth indicated that in most cases deficit irrigation occurred. This increased water use and storage efficiencies, but in most cases, irrigation was insufficient. Range of water application, storage efficiency, deficit/excess efficiency, deep percolation, tail water efficiencies in the farms under experiment, was measured from 10.5 to 95.5, 21.6 to 100, 9.3 to 100, 0.6 to 83.5 and zero to 42.9 percent, respectively.

Irrigation curves showed the effects of initial soil moisture, slope and border dimensions on entrance flow and distribution uniformity of water. Uniformity indices were low and caused huge water loses (about 30-60% of the water that entered the border) by deep percolation especially along the first half of border length. In spite of tremendous amounts of water loss, most crops were under the water stress and deficit irrigation.

Results indicated that traditional irrigation management system was inefficient and had more disadvantages. Lack of farmers' knowledge about soil moisture condition and correct time of irrigation, traditional land and water resource ownership pattern, weak irrigation scheduling as well as imbalance between irrigation system properties lead to water losses and reduced irrigation efficiency.

Practical solutions to enhance irrigation management efficiency are to adjust geometric features of border, based on amount of water entrance, to regulate the cut-off time as well as to determine appropriate irrigation time based on before irrigation soil moisture. There is necessary, in the semiarid and cold regions, to reduce irrigation interval and depth, but in the temperate conditions and smooth lands, irrigation depth and interval can increase.

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