IRRIGATION WITH SALINE WATER IN FARS PROVINCE, IRAN

IRRIGATION PAR L'EAU SELEE DANS LA PROVINCE DE FARSE EN IRAN

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ABSTRACT

Scarcity of fresh water resources is the major constraint for agricultural development in many arid and semi-arid regions of the world including Iran. With the pressure on fresh water resources, the use of non-conventional water resources including brackish, saline and sewage water has received greater attentions in recent years. Before developing sound management practices for use of these resources an evaluation of existing situation is required. The objective of this case study was to evaluate different management practices being employed for use of saline groundwater in irrigated wheat regions of Fars province. This study was carried out in several commercial wheat production regions for three years. In each region three farmers using saline waters were selected. General information on agronomic practices was collected using a questionnaire. Other data including volume of applied irrigation water, soil salinity (ECe) and yield were actually measured for each field. For soil salinity measurement soil samples were collected from upper, middle, and lower portion of a boarder or basin representing different intake opportunity time (Top) at 30-cm depth interval in the root zone. This was repeated five to seven times during the season.

Results demonstrate that waters of much higher salinities than those classified as "suitable for irrigation" are being used for the production of wheat crop. Salinity of irrigation water ranged from 1 to 20 dS/m. About seventy percent of the farms studied produced more than 4 tons per hectare. Root zone salinity profiles show the effect of winter rainfall in addition to large application of irrigation water in reducing soil salinity from an initially high value at planting time in November till March and then rising up with sole application of saline water. To estimate leaching fraction a steady state model was used to predict soil salinity based on irrigation water salinity. At leaching fraction of 45 percent a significant

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correlation was observed between measured and calculated soil salinity for irrigation events at the end of the season.

Key words : *Saline water irrigation, Fars province, wheat, management practices, soil salinity profile.*

RESUME ET CONCLUSIONS

Le manque des ressources en eau douce est la principale contrainte de développement agricole dans des nombreuses zones arides et semi-arides du monde dont l'Iran. Avec la pression sur ressources en eau douce, l'utilisation des ressources en eau non conventionnelles, y compris, saumâtres, salin et eaux usées a reçu une plus grande attention au cours des dernières années. Toutefois, une utilisation continue de ces ressources exige une gestion spéciale pratiques non seulement pour optimiser leur utilisation, mais aussi à réduire leur impact écologique négatif.

Avant d'élaborer saines pratiques de gestion pour l'utilisation de ces ressources, l'évaluation de la situation existante est nécessaire. L'objectif de cette étude de cas était d'évaluer différentes pratiques de gestion employées pour l'utilisation de l'eau souterraines saline en blé irrigué régions de Fars province. Ces études ont été effectués dans plusieurs régions commerciales la production de blé pour trois ans. Dans chaque régions trois exploitations utilisant eaux salines ont été sélectionnés.. Informations générales sur les pratiques agronomiques a été collectées en utilisant un questionnaire. D'autres données y compris le volume d'appliqué irrigation,la salinité des sols (ECe) et du rendement ont été effectivement mesurées pour chaque domaine.Pour la salinité du sol mesure les examplaires du sol ont été recueillies de haute, moyen, et partie inférieure d'un vaste ou bassin représentant différents temps l'occasion d'admission (haut) à 30cm profondeur intervalle dans la zone des racines. Cela a été répété cinq à sept fois pendant la saison.

En général la production de blé dans ce domaine repose sur l'utilisation élevés des semences, d'engrais et d'eau. Les pratiques agronomiques tels que la préparation des terres, méthode d'irrigation et la rotation des cultures ne sont pas optimales. Les résultats démontrent que l'eau de beaucoup plus élevé salinités que ceux qui sont classés comme approprié pour l'irrigation sont utilisés pour la production de récoltes de blé. La salinité des eaux d'irrigation variait entre 1 et 20 ds/m.Environ soixante-dix pour cent de la exploitations étudiées produit plus de 4tons par hectare. La saisonnier appliqué irrigation variait de 6000 à 8000 mètres cubes en plus de 200 à 400 mm précipitations qui se sont produits pendant la saison de croissance. Comparaison des variations saisonnières appliqué l'eau avec l'exigences en eau de la culture dans ces régions(6000 à 7000 mètres cubes dans des conditions normales)montre une grande irrigation pertes qui se produit principalement comme profonde percolation. C'était également représenté en uniforme profils de salinité des sols dans la zone racine. Zone racine salinité profils démontrent également l'effet de précipitations hivernales en outre application à grande d'eau d'irrigation dans la réduction de la salinité du sol initialement haute valeur à la période des semailles en novembre à mars puis monter avec sol application d'eau sale. D'estimer la fraction de lessivage un état stable modèle a été utilisé pour prédire la salinité des sols fondé sur l'irrigation la salinité des eaux. À la fraction de lessivage de 45 pourcent une corrélation significative a été observée *entre la valeur mesurée de la salinité du sol et calculé de la salinité du sol pour l'irrigation épisodes à la fin de saison.*

Sur la base des résultats obtenus dans cette étude, elle est conclu que, bien que relativement bon rendement des récoltes est obtenu en utilisant hautement eau saline,toutefois, en raison de l'utilisation excessive d'intrants notamment l'eau, la durabilité de production dans le domaine n'est pas garanti et des mesures immédiates doivent être prises pour éliminer ces effets negatives. En vertu de ces circumastances, croissante d'eau productivité détient le plus grand potentiel pour améliorer la sécurité alimentaire et de prévenir dégradation de l'environnement.

Mots clés : *Irrigation par l'eau salée, province de Fars, blé, pratiques de gestion, profil de la salinité du sol.*

(Traduction française telle que fournie par les auteurs)

1. INTRODUCTION

Scarcity of fresh water resources is the major constraint for agricultural development in many arid and semi-arid regions of the world including Iran. Based on the projected water needs in 2025, Iran will be in a water scarcity situation. Considering the growing demand for water from other sectors and the fact that 93 percent of renewable water resources is already allocated to agricultural sector, allocation of more water to this sector is not foreseeable in the future.

With the pressure on fresh water resources, the use of non-conventional water resources including brackish, saline and sewage water has received greater attentions in recent years. However, continuous use of these resources requires special management practices not only to optimize their use but also to reduce their negative environmental impact.

Fars Province located in southern part of Iran is the main wheat growing region and ranks first in wheat production and harvested yield in the country. There are three distinct climatic regions in the Fars Province, including the mountainous area of the north and northwest with moderate cold winters and mild summers, the central regions, with relatively rainy mild winters, and hot dry summers, and the southern part which has moderate winters with very hot summers. The central region is the main place for wheat production where this study was carried out. Use of saline water for crop production has a long history here. Management practices employed by the farmers in using these waters are similar to those practiced with the use of non-saline waters. In general, production of wheat in this area is based on using high inputs of seeds, fertilizer and water. Agronomic practices such as land preparation, irrigation method and crop rotation are suboptimal.

The objective of this case study was to evaluate different management practices being employed for use of saline groundwater in the irrigated wheat regions. The evaluation should serve as the bases for future studies to improve management practices for sustainable use of saline water.

2. MATERIALS AND METHODS

This study was carried out in several commercial wheat production regions in Fars Province in southern part of Iran for three years. In each region three farms using saline waters were selected. General information such as cultivation area, depth to water table, time of water application, crop rotation, type and amount of seeds and fertilizer used, was collected using a questionnaire. Other data including volume of applied irrigation water, soil salinity (ECe) and yield were actually measured for each field. Well discharge was measured using cut-throat flume (Walker, 1989) and was converted to depth of irrigation using irrigated area and time of application. For soil salinity measurement soil samples were collected from upper, middle, and lower portion of a boarder or basin representing different intake opportunity time (Top) at 30-cm depth interval in the root zone. This was repeated five to seven times during the season. Salinity of soil saturation extract and chemical composition of irrigation water was measured according to USSL Handbook NO. 60 (1954). Yield was computed based on the total harvested crop from the irrigated area.

3. RESULTS AND DISCUSSION

3.1 Water quality assessment

The chemical composition of some of the well Waters used for crop production in the province is given in Table 1. As it is seen, salinity of waters up to 20 dS/m is used for irrigation. These waters are considered as moderately to highly saline (Rhoades et al., 1992) with severe limitation on use according to criteria given in FAO 29 (Ayers and Wescot, 1985). However, as shown below, relatively good crop yield is obtained using these waters. This emphasizes the point that suitability of saline irrigation water must be evaluated on the basis of the specific conditions of the locality where it is to be used including the crops grown, soil properties, irrigation management, cultural practices, climatic factors and economics.

The sodicity hazard of irrigation waters is evaluated based on the SAR and salinity. Although SAR values for some of the waters are high but due to their high electrolyte concentration soil dispersion and surface sealing should not impose major problem. The potential hazard with the use of these waters is when rains occur during the germination and seedling stage, which could result in poor crop stand as a result of surface crusting.

With highly saline waters, assessment of irrigation water quality should also include ion ratios as well as toxicity factors for specific crops (Pratt and Suarez, 1990). In this regard, Ca deficiency associated with high Mg/Ca ratio and Na is of special concern. Under non-saline conditions Ca requirement of plants are considered to be 0.7-1.5 mmolL-1. The calcium requirement becomes greater under saline conditions since sodium can reduce calcium mobility to the young, developing tissues in the plant (Grattan and Grieve 1998). Calcium deficiency problem has been observed to develop at Mg/Ca>1 for some crops such as barley (Carter et al. 1979) independent of salinity or absolute Ca concentrations. Based on this, Ca deficiency may be of concern with some of the waters used here with high Mg/Ca ratio.

These waters are saturated with calcium carbonate and consequently calcite is expected to precipitate at low leaching fraction throughout the root zone. This was demonstrated using

Watsuit model (Rhoades et al., 1992). At higher leaching fractions, as is the case for many farms in this study, calcite and gypsum is predicted to precipitate at lower depths.

3.2 Yield assessment

Wheat grain yield obtained in the studied farms is shown in Figure 1. It is seen that yield of up to 6500 kg/ha is obtained with water salinity of 10 dS/m. There is a range of yield obtained with the same salinity of irrigation water indicating that other factors are also involved. Some of these factors responsible for the differences in yield among farms are soil type, climate, management practices, and crop variety. Oosterbaan et al. (1990) also observed considerable scattering in field data when yield was plotted against soil salinity. They reasoned that the scatter was due to the presence of many production factors in agriculture, which cannot be all accounted for.

An important factor in evaluating quality of water for irrigation is the amount of yield loss which can be economically tolerated. As shown in Table 2 average yield obtained under saline conditions is about fifty percent of yield obtained under non-saline conditions. Since wheat is considered to be a strategic crop and its purchase is guaranteed by the government with a relatively good price, it has economic advantage over other crops at present. Therefore, there is incentive for farmers to grow this crop even with relatively high yield losses.

Table 1. Chemical composition of irrigation waters used in the studied farms (La composition chemique de l'irrigation de l'eau utilisée dans les fermes étudiées)

Farm No.	EC (dS/m)	pH	Na	Ca	Mg	Cl	SO_4	HCO_3	SAR	Mg/Ca
			$mmol_c$ per liter							
1	11.5	7.17	73.5	24	20	92.5	17	10	12.61	0.83
2	11	7.96	85	20	10	88.7	25	4.8	17.00	0.50
3	8.8	7.79	42	25	16	48	23.7	7	7.31	0.64
4	6.8	7.6	20	16	24	35	23.2	1.8	3.78	0.67
5	6	7.3	36	9	24	60	7.0	2.0	7.86	2.70
6	8.2	7.5	51	10	24	57.5	51.9	5	10.87	2.40
7	1.3	8.26	0.8	4.8	0.2	0.95	1.2	4	0.36	0.042
8	9.7	7.1	70	25	8	85	6.8	5	13.00	0.32
9	10.4	7.11	50	24.5	50.5	59	50.5	6	7.09	2.06
10	10.21	7.85	60	30	21	68	32.3	8	9.43	0.70
11	6.8	7.53	28	20	20	35	18	9.8	5.11	1.00
12	9.18	7.77	48.5	32.5	22.5	57.5	36.5	7.5	7.33	0.69
13	9.8	7.3	64	15	15	84	8.0	2.4	13.49	1.00
14	13.3	7.3	39.84	46.26	56.4	123.5	15.65	4.22	4.62	1.22
15	8.22	7.14	55.28	8.48	16.32	69.25	7.13	4.26	13.55	1.92
16	20	7.8	70.71	73.05	71.44	195.4	21.47	3	6.78	0.98
17	12.5	7.7	73.75	42	18	105	21	2.5	10.33	0.43
18	10.4	6.7	58	30	24	56	52	0	8.95	0.8
19	13	7.1	94.12	13.8	21.6	121.6	3.0	1.9	18.98	1.57
20	14	7.5	40.12	50.13	56	128	13.52	5.2	4.54	1.12

3.3 Root zone salinity

Soil salinity profiles measured for the 2004-2005 and 2005-2006 growing seasons are shown in Figures 2 and 3. Soil salinity is at its maximum during planting time in November but decreases during the rainy season in winter and early spring when most of the rainfall occurs. During this period wheat is in its early development stage with low ET requirements. Therefore rainfall effectively leaches salts from the root zone. Soil salinity then increases again as crop grows and its water requirement is furnished with application of saline irrigation waters. The level of soil salinity in the root zone depends on the amount and temporal distribution of rain. In 2004-2005 total rainfall of 415 mm occurred compared to 320 mm in 2005-2006. As seen in the above figures soil salinity reached a much lower value in 2004-2005 season compared to that in 2005-2006 growing season. These data clearly show the effect of rainfall in reducing the impact of irrigation with saline waters. Isidoro and Grattan (2010) using a simulation model also showed the effect of rainfall and its temporal effect on soil salinity. Their analysis indicated that winter rainfall could be more effective in reducing soil salinity than evenly distributed rainfall throughout the year.

These data show the transient nature of salinity in the field and the contribution of rainfall in this regard. To simulate such situations transient models that include amount of rain and saline irrigation water consistent with actual conditions is required (Letey et al. 2011). These models, however, have had limited field tests due to enormous data acquisition need and variability of field properties among others. On the other hand, steady state models could be used with relatively simple data when conditions are close to meet their assumptions. In the irrigated fields studied here, uniformity of water distribution is poor, and fields are irrigated to supply crop water requirement for the areas receiving the least water. Therefore, heavy irrigations are applied and the change from steady state caused by the rains is rectified. To estimate leaching fraction, a steady state model developed by Hoffman and Van Genuchten (1983) was used to predict average root zone soil salinity based on irrigation water salinity. At leaching fraction of 45 per cent a significant correlation was observed between the measured and the calculated soil salinity for irrigation events at the end of the season (Figure 4).

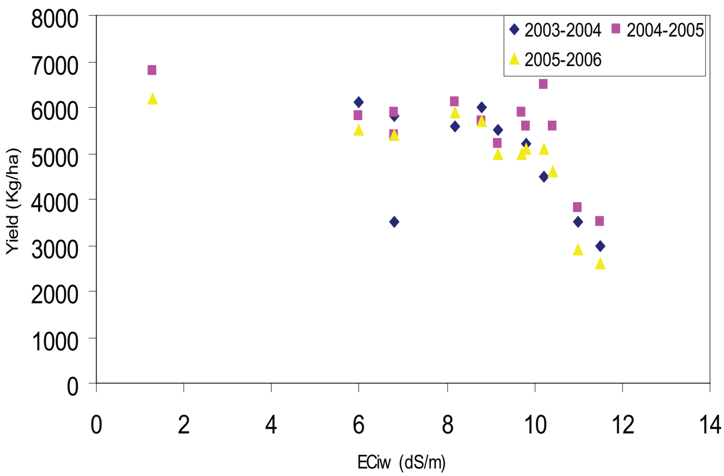

Fig. 1. Wheat grain yield obtained with different irrigation water salinities (Le blé rendement obtenu avec les différentes eaux d'irrigation salinities)

Table 2. Average wheat yield in different region of Fars province (Moyenne production de blé en région différente de Fars province)

Region	Average Yield (Kg/ha)		Relative Yield (%)
	Saline	Non-saline	
Arsanjan	4000	7000	57
Sarvestan	5000	9000	56
Neiriz	3900	7000	56
Darab	4600	8000	58
Fasa	5300	9000	59
Marvdasht	5000	9000	56
Kharameh	4500	5500	82

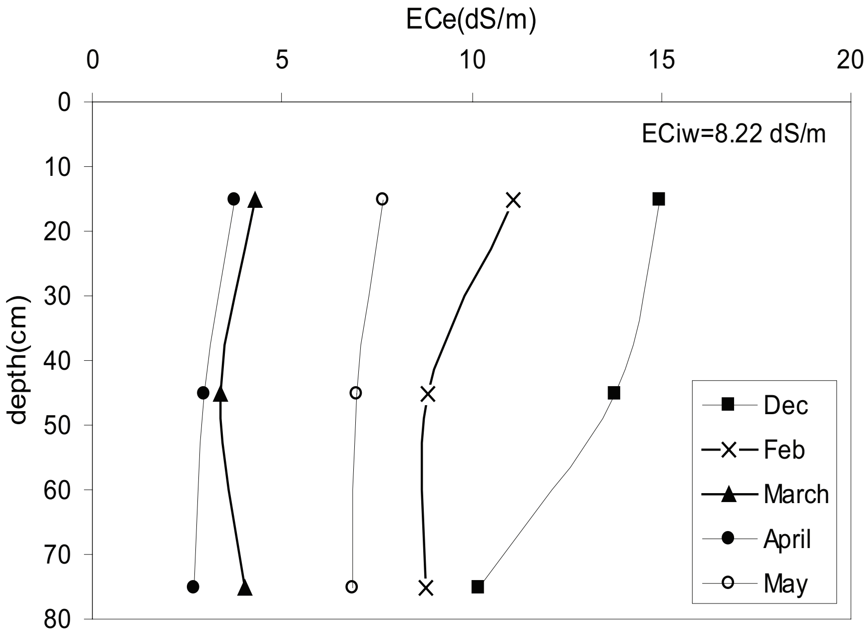

Fig. 2. Soil salinity profile during 2004-2005 growing season (La salinité du sol profil pendant la période 2004-2005 saison de croissance)

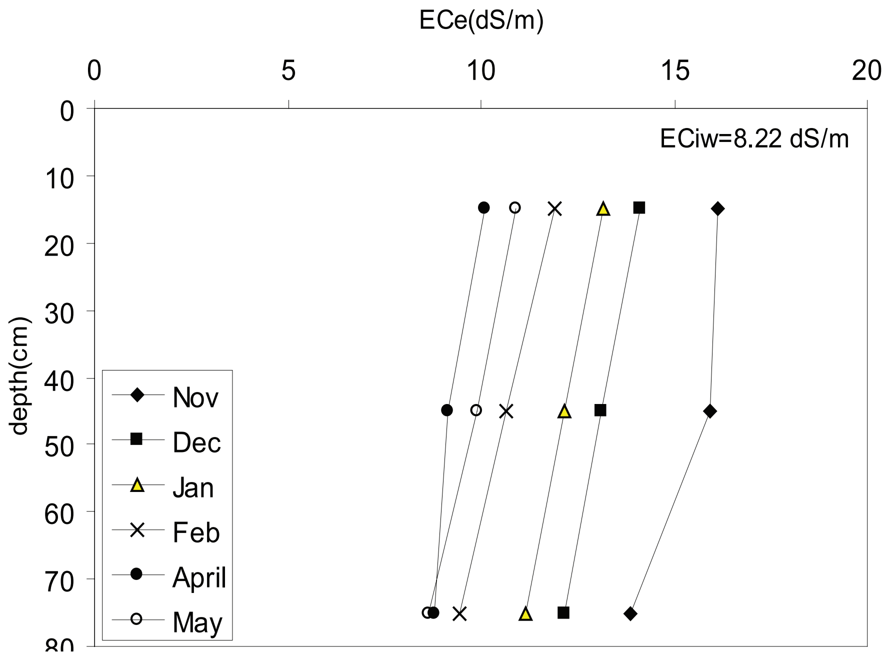

Fig. 3. Soil salinity profile during 2005-2006 growing season (La salinité du sol profil pendant la période 2005-2006 saison de croissance)

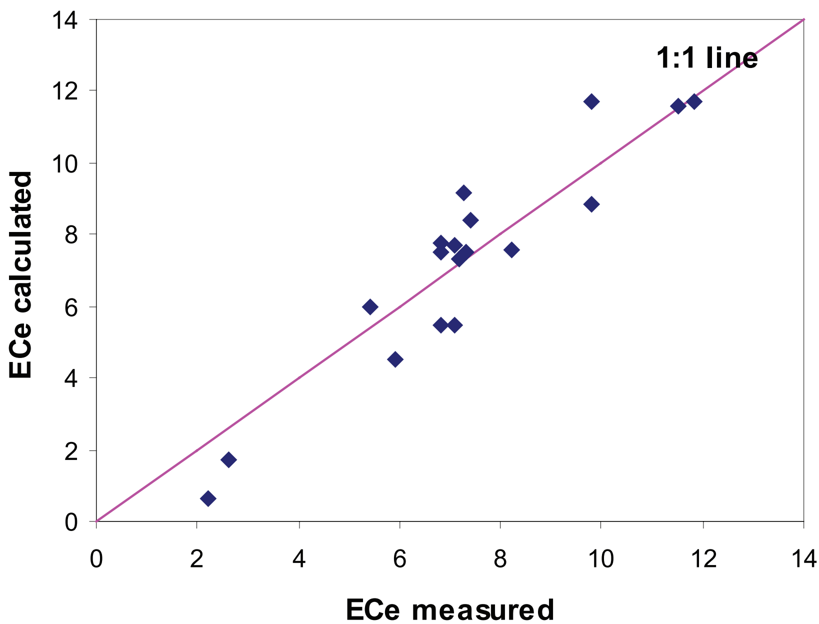

Fig. 4. Measured versus predicted soil salinity at 45 per cent leaching fraction (Mesuré par rapport prédit la salinité du sol à 45 pourcent fraction de lessivage)

3.4. Water consumption

On-farm water application rates are generally high in the province. Seasonal applied water for some of the farms given in Table 3 shows an average of 7600 m^3/ha compared to the average national applied water for wheat, which is about 6400 m^3/ha (Keshavarz et al. 2003). This water is applied in 5 to 6 irrigations during the season with the first one after planting time in November and the rest after the rainfalls in March through May in 10 to 15 days irrigation interval. Wheat water requirement under standard condition (no stress) was calculated to be between 6000 to 7000 cubic meter in the region using the FAO Penman-Monteith method (Allen et al. 1998). Considering the 200 to 400 mm of rainfall which occurs during the crop growing season and the fact that actual crop water use of wheat is less than the potential ET due to the stresses affecting crop growth, the amount of applied water should cause great irrigation losses occurring mainly as deep percolation.

The main reason for high irrigation losses is the ineffective surface irrigation method used by the farmers. Farmers typically cultivate their field in long strips, and then divide them in small inter-connected basins with the size of 10m × 10m. Water is conveyed from one basin to another until the whole field is irrigated. This results in poor uniformity and large application of irrigation water. Instead, if long border strips irrigated from one end could be used, one would expect that uniformity would improve and applied water would be reduced. In an attempt to demonstrate this, Cheraghi and Dehqanian (2006) compared applied water and yield under farmer field situation with small basins and recommended long border strips. Surface irregularities in the border strips were leveled with a tractor driven leveler. Results of this study showed that considerable improvement could be made with the change in the irrigation method. Seasonal applied water was reduced from 6100 cubic meter under farmer's situation to 4400 cubic meter in the proposed trail, about 30 percent decrease in water application, and yield was improved by 10 percent from 4460 Kg/ha under farmer's condition to 4890 Kg/ha in the experimental trail.

With the introduction of laser-controlled land leveling and modern agricultural machinery farmers are expected to adopt modern surface irrigation methods. Adoption of such irrigation practices would reduce labor and energy costs, improve uniformity of application, lower water application, increases efficiency, reduces nutritional losses, improve crop yield and prevent environmental degradation. Moreover, it ensures sustainable production when scarcity of water becomes severe as it has occurred recently due to the long period of drought.

Table 3. Seasonal applied water in cubic meter per hectare in some of the fields (Saisonnières appliqué l'eau. dans mètres cubes)

ECiw, dS/m	Applied Water, m^3/ha	Yield, Kg/ha
13	8300	3200
7.5	7900	3800
13.3	7600	4660
8.1	7100	2700
9.8	8000	4150
12.5	7500	4375
11.2	7400	4660
9	8200	1880
8	7600	4750
10	6800	4900
7.8	7400	6070
8.5	8100	5400
8.3	7500	2750
6.5	7200	5100
14	7900	3100
12.5	8470	6054
14	6400	1800
11.5	7500	2700
8.3	8200	2140

4. CONCLUSIONS AND RECOMMENDATIONS

Based on the results obtained in this study it is concluded that although relatively good crop yield is obtained using highly saline water, however, due to overuse of inputs especially water, sustainability of production in the area is not secured and immediate actions must be taken to remove some these negative impacts. Under these circumstances, increasing water productivity holds the greatest potential for improving food security and preventing environmental degradation.

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