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Field evaluation of SWAP model under different irrigation management practices for wheat yield

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ABSTRACT

The agro hydrological model SWAP3.03 was used for two wheat crops, cultivars “Ghods” and “Rowshan” under different irrigation regimes. The field study was conducted during 2005-2006 growing season in the Research Field of Birjand University. Different qualities of irrigation water (namely 1.4, 4.5 and 9.6 dS/m) obtained from three local wells were used in a factorial plot design with four levels of water depths (namely, 50, 75, 100 and 125% of ET_c). The model was initially calibrated with respect to the winter wheat crop coefficients, based on a study in the province of S. Khorasan. The simulated values fitted well the trend of actual crop production for various amounts and qualities of irrigation water. Maximum yield was obtained for a deficit irrigation of 75% ETc with the best water quality, that of 1.4 (dS/m). Results also showed that different levels of water and salinity stress would affect crop production. The correlation coefficients between the simulated and actual crop production were 0.72 for “Ghods” and 0.83 for “Rowshan”, both statistically significant at 1% level. As compared to the actual yield, the Average simulated yield was 15% higher for “Ghods” and 10% lower for “Rowshan”. *A t-test showed that such* deviation between simulated and observed values were not lower than required for significant differences. *The results of this study*, therefore, show that SWAP3.03 model is a useful tool to estimate wheat production under different levels of water and salinity stress.

Introduction

Salinity is a major threat to irrigated landscapes and waterways in many parts of the world (van Schilfgaarde, 1974; Ritzema, 1994; Ghassemi et al., 1995; Tanji and Kielen, 2002). Salinity impacts soil and water quality and crop production and causes serious off-site environmental degradation (van Hoorn and van Alphen, 1994). Consequently, salinity is one of the most challenging environmental problems facing irrigation landscapes around the world, including Iran.

A range of methods are available to manage salinity and claim saline soils and water in irrigated regions to optimum yield and high water use efficiency. Amounts of yield with SWAP model predicted by Kiani and colleagues (2005), Evis and colleagues (2000) ,Pasargad and colleagues(2006) .Guantivar and Esmout (2006)also in their research on wheat ,maize ,cotton reported that they can increase water consuming efficiency between 15 to 30 percent by decreasing water consumed by crop from 20 to 30 percent when there is water shortage.

Most of salinity stress and water stress studies have been carried out separated and data are available for only one of these stresses. It is well known that water uptake is reduced due to salting, but it is not yet clear how plants react when low soil water pressure head occurs together with low osmotic head. In the earliest studies (Wadleigh and Ayers, 1954, Wwadleigh.et.al.1946.us Salting Laboratory statt.1954). In this study water stress and salinity stress have carried out together. In this research; Data collected during the 2005–2006 irrigation season in the Khorasan province of Iran irrigation season were used to calibrate the soil–water–atmosphere–plant (SWAP) model. SWAP satisfactorily simulated components of the water and salt balance when compared to the collected hydrologic data.

Materials and methods

In this part of the study, different levels of salinity (S1, S2 and S3) and water stresses (W1, W2, W3 and W4) have been applied to Ghods and Roshan varieties of wheat crop simultaneously, using an individual reference treatment R for each water stress level. The field study was conducted during 2005-2006 growing season in the Research Field of university Birjand in Iran. Water and salinity stresses were applied to wheat crop after healthy plants had developed. The target water applications were 50, 75, 100 and 125% of the reference ET for W1, W2, W3 and W4, respectively. The irrigation water salinities were 1.5, 4.5 and 9.6 dS/m for S1, S2 and S3, respectively. The experiment was carried out on in a factorial split plot design with 3 replicates. The treatments consisted of four levels of irrigation (50, 75, 100 and 125% of crop water requirement (based on ET), and three water qualities (1.4, 4.5, 9.6 dS/m).The Irrigation system and experimental blocks are shown in Fig. 1 All possible combinations of the mentioned water and salinity stresses with their own references were applied? variations of soil water content, soil water pressure head, and osmotic head distributions in the root zone were obtained by varying the quantity of applied water, irrigation intervals, and irrigation water salinities. Table 1 and 2 present Chemical and physical properties of soil and water supply well.

SWAP simulation model

SWAP simulates soil water movement using Richards, equation.

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$$\frac{\partial\theta}{\partial t} = C_W(h)\frac{\partial h}{\partial t} = \frac{\partial}{\partial z}[K(h)(\frac{\partial h}{\partial z}+1)] - S(h) \quad (1)$$

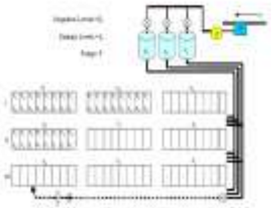


Fig. 1. Schematic plan of experimental field

where t=time (day), h=the soil water pressure head (cm) ,C_W (h) curve gradient of soil water content (cm $^{-1}$) ,Z=positive upward vertical interval from soil surface (cm) ,K(h) hydraulic conductivity is as function of volumetric soil moisture content(cm/day), S=is function of water absorption in crop root (cm ^{3}.cm^{-3}. s $^{-1}$).

The relation between soil water content, hydraulic head (h) and hydraulic conductivity coefficient is called the soil hydraulic conductivity function. In SWAP model, Van Genuchten - Mualem proposed experimental functions are used to define soil hydraulic function.

$$\theta(h) = \theta_{res} + \frac{\theta_{sat} - \theta_{res}}{\left[1 + |\alpha h|^n\right]^{\frac{n-1}{n}}} \quad (2)$$

Where θ_{res} is residual moisture content (cm ^{3}.cm^{-3}), θ_{sat} saturated moisture content (cm ^{3}.cm^{-3}), α and n (-) are empirical constant affecting the shape of the retention curve. Hydraulic conductivity function is defined as below:

$$K(\theta) = K_{sat} S_e^{\lambda}\left[1-(1-S_n^{\frac{n}{n-1}})^{\frac{n}{n-1}}\right]^2 \quad (3)$$

Where K_{sat} is saturated hydraulic conductivity and S

$$S_e = \frac{(\theta - \theta_{res})}{(\theta_{sat} - \theta_{res})} \quad (4)$$

And λ is experimental coefficient (dimensionless). Upper boundary conditions are defined by potential evapotranspiration behaviors, irrigation and rainfalls. Potential evapotranspiration according to penman Manteith ‘s equation is calculated by using daily hydrometeorology data such as solar radiation, temperature ,relative humidity ,wind speed ,and crop specification data.

By using a simple algorithm or detailed model one, can simulate crop growth. The detailed model has the simulation advantage of potential (Y_p) and real (Y) dried material‘s performance. Growth speed of dried material (kg of dried material per hectar per day) by calculating absorption and potential and gross material making (capture of carbon) presents A_{max} =maximum stabilization speed ,ε_{PAR} initial gradient or photo consuming output and speed of absorbed sunshine in a given depth as L in canopy.

Momently of speed of absorption in leaf layer must be measured based on canopy leaf area index and in a whole day. Inserting water stress and salinity stress is done by crop to quantity and non mixed real stabilization. Part of absorbed materials and produced materials is used to provide energy for stabilization and crop respiration. Absolute speeds of remained absorption are integrated for whole time, for example crop growth season, and by using of glucose transformation coefficient to dried material is transformed to dried material’s performance.

$$Y = C_e \sum_{i=1}^{N} \left(\frac{30}{44} TT_p^{-1}(t) - R_m(t)\right) \quad (5)$$

Where R_m is real speed of respiration and N is total term of growth. C_e is referred to CO_2 transformation to glucose. Produced dried material in roots, leaves, stems and potential organs are divided by using transformational coefficients which are functions of crop growth stage. Special increasing in dried material and specified leaf area index define activity of leaf area index. In salinity and water stress, SWAP reduces potential dried weight to dried weight. It must be noted that effects of nutrition , plagues, weeds and diseases on crop growth and its production has not applied in SWAP model.

SWAP Input

Input data of SWAP model which are used in performance simulation included climatic, agricultural, soil specification and managerial information are defined by model in given file formats.

Climatic data

A model for calculating potential evapotranspiration by Penman Monteith equations requires forecast data such as sunshine, minimum and maximum daily temperature, humidity, sunny times, average wind speed in 2m altitude and daily rainfalls. These data are calculated from synoptic station of the organization in 2005-2006 as well as and daily sunshine based on Penman -Monteith method and provided to model.

Soil hydrological properties

The soil profile was divided into 3 layers and 60 strata and specification of each layer such as percentage of composing particles (soil texture), root infiltration limitations, hystersis event and initial humidity conditions are defined in a related file. Then for defining given relations of water content's head, soil moisture content and unsaturated hydraulic conductivity coefficient for each layer in soil profile ,coefficients of Van Genuchten are provided to model .to obtain these parameters ,RETC model has been used, in way that specification of each layer that are given in table 3 such as percentage of composing particles and soil bulk density are given to model as input data and amount of α and n and other simple parameters of Van Genuchten –Mualem equation including θsat and θ_{res} and Ks are obtained as output. Need to rewrite this last sentence to be clearer. The specification of estimated hydraulic parameters by RETC model is illustrated in table 3.

Irrigation parameters

Irrigation plans and applying different water regimes, based on lack of soil moisture content and using treatment with water stress as measure and applying coefficients of each treatment, is done by:

$$SMD = (W_{fc} - W_i).A_s.D.C$$

Where SMD= soil moisture deficit, W_{fc} and W_i are weight percentage of soil moisture in field capability and available moisture, A_s =soil bulk density, D is depth of root development and C is coefficients of each treatment.

Treatments of water irrigation were used to provide 50, 75, 100, 125 percentage of crop need of irrigation (based on ET) after germination. Irrigation planning in this layout includes planning and amount of each irrigation for different treatments, which are given in table 4.

By using designed irrigation order per each block on the surface of field, different combination of quality and quantity of irrigation water is addressed. Therefore, by collected data during performing the plan, a file has been made for irrigation specification. Input information to model includes irrigation date, depth of water irrigation, and salinity of water and irrigation method.

Crop parameters

SWAP model includes three main parts in a file for growth simulation input data and performance estimation of agricultural products: 1.detailed model of growth simulation 2. Detailed (gross only) which is assigned to growth and development of grass.3.simple model for estimating performance of agricultural products (Huygens et al, 2000). In this study, detailed model of growth simulation is used for prediction of relative performance. Some of the needed parameters for this section in each stage of growth include :crop height, root depth , crop coefficient , leaf area index, absorption factor and transformation to dried material , dividing dried material coefficient to organs, crop's water consuming , crop tolerance threshold to salinity, photo consuming output, special area of leaf, total temperature from planting to flowering and total temperature from flowering to harvesting. Requirement information for this section is collected from studies and different resources which measured these parameters for Khorasan Province.

Statistical criteria

Modeling performance was assessed using simulated and measured crop yield. Different criteria have been proposed for evaluation modeling performance.

For this study, it was thought to be sufficient to assess whether there is a bias in the simulated results, how much scatter there would be around a 1:1 linear relation between simulated and measured values and how large the maximum error is. Hence, we used maximum error (ME), root mean squared residual error (RMSE), Coefficient of Determination (CD), Modeling Efficiency (EF) and Coefficient of Residual Mass (CRM):

$$ME = \max\left|P_i - O_i\right|_{i-1}^{n} \quad (7)$$

$$RMSE = \left[\frac{\sum_{i-1}^{n}(P_i - Q_i)^2}{n}\right]^{1/2} \times \frac{100}{\bar{Q}} \quad (8)$$

$$CD = \frac{\sum_{-}\sum_{i-1}^{n}(P_i - Q_i)^2}{\sum_{i-1}^{n}\left(Q_i - \bar{Q}\right)^2} \quad (9)$$

$$EF = \frac{\sum_{i-1}^{n}\left(Q_i - \bar{Q}\right)^2 - \sum_{i-1}^{n}(P_i - Q_i)^2}{\sum_{i-1}^{n}\left(Q_i - \bar{Q}\right)^2} \quad (10)$$

$$CRM = \frac{\sum_{i-1}^{n}Q_i - \sum_{i-1}^{n}P_i}{\sum_{i-1}^{n}Q_i} \quad (11)$$

Here, Pi are the simulated values and Q_i are the observed values, n is number of samples, $\bar{Q}$ is observed average value, ideally, the values of all criteria should be close to zero. All criteria were calculated for each site using all available data.

Minimum amount of ME, RMSE, CD is zero. Maximum amount of EF equals to one. EF and CRM can have negative amounts. High amount of ME, presents the worst mode of model performance while RMSE presents the amount of over or under estimation amount in comparing with measurements" Index presents scatter ratio between predicted amounts and measurements. EF Index compares predicted amount with measured amounts. Negative EF shows average amount has better estimation than predicted amounts. All amounts were equal, numerical amount of RMSE, ME, CRM Indexes are equal to zero and amount of EF and CD equals one.

In this research all the statistical criteria are for comparing reduction percentage of real performance given in field study and amounts of reduction percentage for predicted amounts by a model for two products and irrigation frequency has calculated differently. To calculate water consuming efficiency performance in surface unit divided in total irrigation water and rainfalls in surface unit. Index of water consuming efficiency can be the best and suitable index to determine low irrigation treatment. Because the amount of rainfalls has impact on crop yield in dry farming and irrigation condition, its amount in calculating WUE have mentioned (Sepaskhah et al, 2006).

Results and discussion

Model Calibration

Three variables were used for calibration: (a) The low boundary condition (b) The attention coefficient for net radiation, and (c) The function describing root water uptake. As described in section 3, water tends to accumulate at the interface between the upper and lower soil layers. We took this feature into account by specifying the lower boundary condition as pressure head being zero at this interface a depth of 1 m. This considerably improved agreement between simulated and observed soil water content. Data for calibration of model was used from two years (2003, 2004). Then, model with different kind of combination based on real scope was calibrated manually.

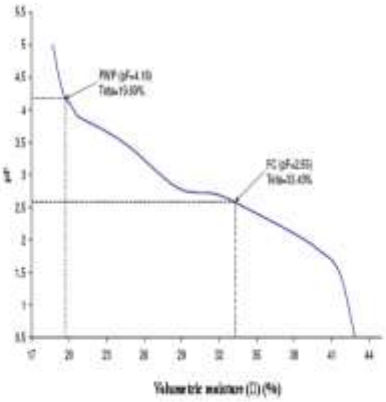
In this research, performance of two wheat cultivars (Ghods and Roshan) were calibrated by using data from model and details for data were simulated in different treatments. To evaluate model we used last simulated point at growth season in which amount of dried material is important. To assess the impact of irrigation on performance of two kinds of wheat (mention before) under different treatments like salinity and water shortage , production function according to consuming water for two amounts were defined separately. Tables 5 and 6 present performance amounts and WUE for actual and simulated yield by model in three stages of salinity.

Comparing results of prediction by SWAP model with actual results from (2005-2006) showed that model predicted of reduced performance from deficit irrigation and salinity for Ghods lower that real amounts and for Roshan higher than real amounts of yield and WUE.

Hagan and Stewart (2006) also reported that total biomass or part of crop with economic value has a linear relationship with ET. Comparing figures for Ghods and Roshan in three salinity stages shows that Roshan is in higher than Ghods and it means that under salinity conditions (low or high) Roshan has better performance that Ghods.

Change trend of curves in two kinds the same but one difference which is in each three salinity stages , gradient of curves related to Ghods is more than Roshan and this means that increasing production per increasing one unit of consuming water in salinity condition is higher in Ghods. In other words, sensitivity of Ghods to irrigation shortage and salinity is higher and Roshan is more resistance to irrigation shortage and salinity. In assessing performance of two kinds of wheat in two salinity treatment, Yazdani (1992) found that in high salinity the performance of Roshan is more than another.

Determining the best treatment for irrigation shortage when we have water shortage is using water use efficiency index .This index for each amount and also predicted amounts by model has calculated. WUE results for two kinds of wheat have shown in Tables 5 and 6.



Predicted amounts by SWAP model related to WUE are same as real results. In all modes, model shows the most WUE in S_1I_2 treatment.

Estimation model in assessing performance and WUE for all treatments were higher for Ghods and lower for Roshan than real results so we have to consider this in our research.

These results shows that first, the magnitude of yield reduction associated with salinity and deficit irrigation was greater for Ghods that that for Roshan cultivar, thus indicating that the former is more sensitive to these stresses that the latter cultivar.

Second, for two kinds of wheat , water stress and salinity in environment because of each extra impact in reducing water free energy, makes higher tribulation in water absorption that at last affected performance more and this result is compatible with most researchers (Paro and Romero, (1980); Sepaskhah and Bursa, (1979);Homaee et al.

(2002, a, b, c), Kiani et al., (2005). Water use efficiency is greater for Rorshan than that Ghods.

Maximum efficiency for water consuming in different treatments is always related to I2 treatment (75% required amount for crop) and S1I2 treatment has the highest output for two kinds as 6.23 (Ghods) and 6.78 (Roshan) Per Hectare /Millimeter and because I2 treatment is water shortage treatment therefore we can conclude that water use efficiency in irrigation shortage treatments are more than depths in which consuming water is higher.

Therefore in these treatments we affront with deficit of water sources based on water use efficiency , it is more rational that instead of supplying 100% of crop need , we supply 75% of it and use 25% extra in fields which are under hard water stress. In this way we can optimize total efficiency.

Predicted amounts by SWAP model Kiani and colleagues(2005), Evis and colleagues(2000) ,Pasargad and colleagues(2006) , Guantivar and Esmout also in their research on wheat ,maize ,cotton reported that we can increase water consuming efficiency between 15 to 30 percent by decreasing water consumed by crop from 20 to 30 percent when there is water shortage.

By comparing performances from model and measured in field (Fig 3) showed that there are a good agreement between simulated and measured performance in field.

Curve of consuming water –performance from model is same as function from field with movement from high depth of irrigation to lower depth difference in real and simulated amounts is increased.

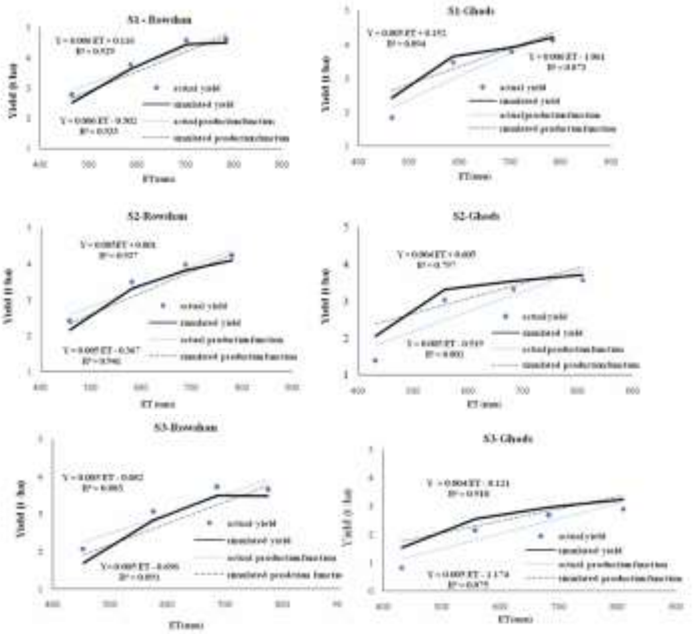


Fig. 3. Curve of consuming water –yield in different levels salinity

Difference of simulated and real yield is because of only model to calibrated crop parameters and soil specification parameters in calibration are not considered. But in SWAP model until the soil is wet ,soil real evaporation flux (E) is affected by atmospheric request and equals with potential evaporation .but in arid conditions ,it is controlled by maximum soil water flux in upper layer .in this model parameter (E_{MAX})according to these relations are defined by van Genuchten equation in this model. Results are affected by equation parameters especially α, n, K_S.

Simulated performance in different levels of salinity

To assess how salinity is distributed in soil profile, we used average seasonal salinity. Salinity distribution in soil profile in treatment complete irrigation are uniform than treatments under water stress (I_1, I_2). Due to increase of water, infiltration increases and distribution of salinity will be uniform. Maximum non-uniform are observed in treating water stress and salinity (S_3, I1). Results also show that distribution of salinity in soil profile is along with increasing soil salinity and it is seen with salinity of saturated soil especially when it is increased in soil layer. Comparing salinity in soil profile at the beginning and end of season shows rising in salinity in soil profile that this trend in low salinity treatments are smaller(S_1) and in high salinity treatments are greater(S_2,S_3).

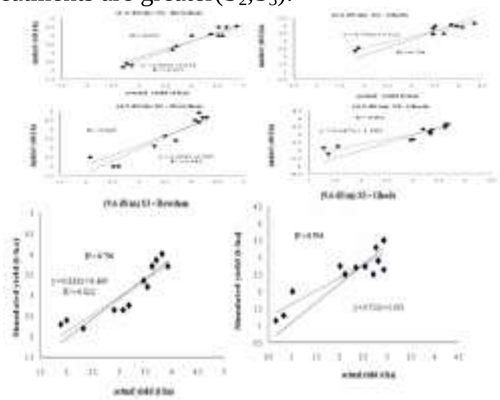


Fig.4. Correlation between actual and simulated yield of Wheat cultivars by swap model in different salinity

Decreasing in water use efficiency, as you can see in these figures, distribution pattern of real and simulated performance are affected by changes in depth of irrigation and distribution of soil salinity and salinity of irrigation water. According to figures, in the same depth of irrigation, performance is changed in different salinity and same as other researches, salinity more than dS /m leads to decreasing wheat performance.

To assess impact of salinity in estimating wheat performance the correlation coefficient between measured and simulated performance was calculated in different salinity stages .results show that performing salinity treatments leads to decreasing model accuracy in estimating of two wheat performance. Factors which results in decreasing performance are aridity and salinity stress. SWAP model considers decreasing performance result from aridity and salinity stress based on multipliable absorption equation (van Genuchten.1978) as product of water stress factor (a_{rw}) multiplied by salinity stress (a_{rs}).

$$\alpha(h,\pi)=\alpha(h)\times\alpha(\pi)$$

While several researches in estimating absorption models shows that multipliable models does not have physical basis and cannot distinguish between water energy elements in soil , impact of each and possibly this element results in less accurate model in salinity and aridity stress at the same time.

Evaluating simulation of different kinds of wheat‘s performance by SWAP model

To evaluate reliability of results from model predictions used by statistic Indices. Results of this analysis have shown in table 7.

Scatter ratio between measured and predicted values (Fig 5)

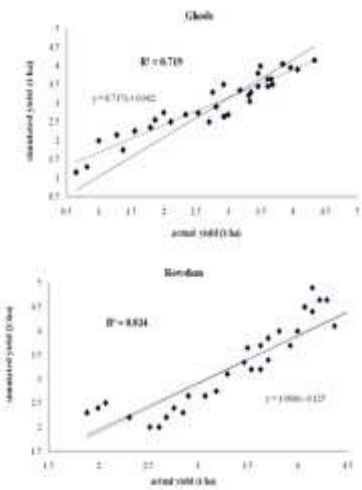


Fig.5. Simulated yield of Wheat cultivars by swap model in comparison to actual yield

shows by SWAP model that R^2 for Ghods and Roshan species are 0.72 and 0.834, respectively. Moreover, t test (α=0.05) revealed that there was no significant difference between the estimated values of the two methods against the real measurements. This results show that the highest correlation can be seen in real and simulated data in Roshan performance and the lowest can be seen in Ghods. According to so many years planting the Roshan species in this region, now it is considered as local species and it is possible to have high amount of R^2. On the other hand we have seen that Ghods species has higher sensitivity than Roshan sensitivity and this possibly results in less accuracy of SWAP model to simulate Ghods species. In total, it can be said according to R^2 variation on field scale model has good compatibility to simulate wheat performance in this region. According to this, Akbari (2004) determined R^2 coefficient for wheat and beet in Esfahan, 0.87 and 0.85, respectively. Furthermore, using F test (α=0.05) (Snedecor and Cochran 1967), it was found out that although there were no significant differences between the slopes of the fitted linear regression lines (y=ax+b) with 1:1 line (y=x) i.e., the intercept of 1:1 line (y=x), differed significantly from Zero.

According to what mentioned in table, maximum error in prediction model for Ghods species and minimum is for Roshan species. This means that SWAP model in estimating performance of Roshan species has less error. Minimum amount of RMSE is related to Roshan species that results from better estimating model and second preference is related to Ghods wheat with RMSE=15.34.

Amount of EF index presents model efficiency in simulation and amount of Ghods and Roshan are calculated as 0.814 and 0.784.and this shows that SWAP model in stimulating performance of wheat species on field scale has high efficiency.

Coefficient of determination (CD) between model results and field results also in Ghods species are lowest and in Roshan species are the highest. This means that distribution of prediction model‘s results and field results based on performance of Roshan wheat have lowest distribution and in Ghods wheat have the highest distribution.

Coefficient of residual Mass (CRM) represents tendency of model to estimate more or less amount in comparing with measurements. This amount for Ghods is -0.0708 and this shows that performance model of Ghods species in most cases are more than what predicted in real conditions. But this positive amount for Roshan shows that this model in most cases estimates performance of Roshan species less than real amounts.

Conclusion

Evaluation and calibration of each model needs to perform different levels and change coefficients which affect on outputs. Using these coefficients must be compatible with especial climatic- agricultural condition in region to achieve the rational results.

Results show that output data of SWAP model have high sensitivity to depth of irrigation. Sensitivity degrees are related to sunshine parameters, leaf area index, maximum temperature, and hydraulic conductivity of soil surface layer, rainfalls, salinity of irrigation water and depth of roots developments.

Simulated yield same as measured in different amount of salinity of water irrigation and soil salinity shows that salinity of soil and water more than 6 dS/m , affect wheat yield and this is not only affected by water irrigation.

SWAP model after calibration based on South Khorasan province‘s conditions with differences between predicted and measured (10 percent for Roshan and 15 percent for Ghods could estimated total trend of changes in different amounts of water irrigation and high salinity. The highest correlation of simulated and real data resulted from Roshan species and the lowest in Ghods species. We concluded from results of analyzing sensitivity, calibration and accuracy and estimating SWAP model that this model has considered efficiency for estimating wheat performance in South Khorasan and in salinity and water shortage and field scale. It can be predicted if we calibrate model for soil condition and water and mineral transfer in field, it can be simulate production performance more accurately in different managerial ways of irrigation.

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Table 1.chemical and physical properties of soil

percentage of soil particle			Soil texture	Bulk density (g/cm^3)	EC (dS/m)	pH	soil depth (cm)
Clay	Silt	Sand					
35.7	34.6	29.7	C-L	1.5	2.1	7.61	0 - 30
37.3	52.6	10.1	Si-C-L	1.45	2.7	7.72	30- 60
35.2	53.6	11.2	Si-C-L	1.39	2.9	7.78	60- 90

Table 2. Chemical and physical properties of Water supply well

Anions				Cations				SAR	pH	(EC) dS/m	Well. No.
SO_4^{2-}	CO_3^{2-}	HCO_3^-	CL^-	K^+	Na^+	Mg^+	Ca^+				
4.1	-	3.1	7.2	0.05	10.2	1.7	2.2	7.4	8.0	1.4	1
16.5	-	8.3	21.2	0.3	26,5	4.7	14.	8.6	7.8	4.5	2
20.8	-	10.6	53.5	0.8	43.8	12.8	27.6	9.7	7.7	9.4	3

Table 3.parameters of van Genuchten, s equation

Depth (m)	n(-)	α (cm^{-1})	K_{sat}($cm.d^{-1}$)	Θ_{sat}($cm^3.cm^3$)	Θ_{sat}($cm^3.cm^3$)
0-30	1.3861	0.0127	5.84	0.4184	0.0819
30-60	1.4527	0.0096	6.53	0.4483	0.0896
60-90	1.4835	0.0090	9.52	0.04593	0.0893

Table5. Performance amounts and WUE for Roshan Wheat and model in three stages of salinity

Salinity	treatments	Total depth of irrigation and rainfalls	Roshan		Model	
			Yield	WUE	Yield	WUE
S1	50%water need	431	2765	6.41	2575	5.97
S1	75% water need	557	3777	6.78	3625	6.5
S1	Full irrigation	683	4586	6.71	4450	6.47
S1	125% water need (high irrigation)	809	4592	5.78	4733	5.85
S2	50%water need	431	2401	5.57	2167	5.03
S2	75% water need	557	2500	6.28	3395	6.10
S2	Complete irrigation	683	3975	5.81	4145	6.07
S2	125% water need (high irrigation)	809	4222	5.22	4383	5.42
S3	50%water need	431	2607	4.79	1850	4.29
S3	75% water need	557	3055	5.48	2895	5.2
S3	Complete irrigation	683	3716	5.44	3485	5.1
S3	125% water need (high irrigation)	809	3642	4.5	3416	4.22

Table. 4. Time (date) and consumed water (mm) in each irrigation treatment.

Irrigation time	First treatment (50% of water need)	Second treatment (75% water need)	Third treatment (100% water need)	Fourth treatment (125 %water need)
16 Nov 2005	30	30	30	30
24 Feb 2006	35	53	70	87
10 Mar 2006	38	57	76	95
24 Mar 2006	45	68	91	114
16 Apr 2006	49	73	97	121
27 Apr 2006	45	67	90	113
7 May 2006	40	60	80	100
Total (mm)	282	408	534	660
Total (m^3/ha)	2820	4080	5340	6600

Table 6. Performance amounts and WUE for Ghods Wheat and model in three stages of salinity

Salinity	treatments	Total depth of irrigation and rainfalls	Ghods		Model	
			Yield	WUE	Yield	WUE
S1	50%water need	431	1821	4.22	2417	5.61
S1	75% water need	557	3473	6,23	3750	6.73
S1	Full irrigation	683	3787	5.54	3867	5.66
S1	125% water need (high irrigation)	809	4123	5.09	4003	4.95
S2	50%water need	431	1401	3.25	2117	4.91
S2	75% water need	557	3043	5.46	3210	5.76
S2	Complete irrigation	683	3332	4.87	3546	5.19
S2	125% water need (high irrigation)	809	3580	4.42	3718	4.59
S3	50%water need	431	821	1.9	1482	3.44
S3	75% water need	557	2175	3.9	2550	4.58
S3	Complete irrigation	683	2645	3.87	2945	4.31
S3	125% water need (high irrigation)	809	2889	3.57	3225	3.98

Table 7. The value of statistic indices for evaluating of Swap model performance

Crop	R^2	ME (t/ha)	RMSE	CD	EF	CRM	$\bar{Yo}$ (t/ha)	$\bar{Ys}$ (t/ha)
Ghods	0.719	1.0	15.34	0.12	0.81	0.0278	2761	2979
Roshan	0.834	0.752	10.64	0.185	0.784	-.0708	3519	3418