ASSESSMENT OF WHEAT WATER USE EFFICIENCY IN DIFFERENT DEFICIT IRRIGATION SENARIOS AND UNDER CLIMATE CHANGE CONDITION

EVALUATION DE L'EFFICACITE DE L'UTILISATION D'EAU DANS LA CULTURE DE BLE DANS LES DIFFERENTS SCENARIOS DU DÉFICIT D'IRRIGATION ET SOUS LE CHANGEMENTS CLIMATIQUES

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ABSTRACT

The development of water-conserving agricultural practices is essential in order to limit agricultural water overuse. To find an effective way to save water in the wheat-growing season without markedly reducing wheat yield, the CropSyst simulation model was calibrated, validated and used to simulate water use by spring wheat in Varamin plain. Dry (1998-99), normal (1985-86) and wet (1997-98) growing season during 1980-2009 were determined. The CropSyst simulated wheat grain yield for different deficit irrigation scenarios in each growing season. Using Arc CS we performed spatial water use efficiency analysis. For this, weather region, soil and cropping system map were prepared and with GIS software they were overlaid and combined simulation map obtained. The A2 emission scenario as reported by IPCC was used and weather data were generated for the period of 2011-2040 by the ClimGen model.

The result show that in the wet growing season the potential yield average (7938 kg ha^{-1}) is higher than dry (7725 kg ha^{-1}) and normal (6811 kg ha^{-1}) growing season. The results further show that water productivity in wet, normal and dry growing season on base of Tr were 2.01 (occurs in 50% Irrigation Requirement scenario), 1.95 (40 % IR) and 2 (40 % IR) kg m^{-3} and on base of ET were 1.5 (70 % IR), 1.25 (80 % IR) and 1.4 (70 % IR) kg m^{-3} and on base of water entering soil profile were 1.38(50 % IR), 1.04 (60 % IR) and 1.2 (40 % IR) kg m^{-3}, respectively. The analysis in climate change condition showed that average water productivity on base

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of ET, Tr and water entering soil profile in period (2011-2040) decreased about 13.78, 1.62 and 9.04 % observed optimum irrigation in normal growing season WUS values, respectively.

Key words: *Climate change; ClimeGen; CropSyst model; Deficit Irrigation; Varamin; Wheat.*

RESUME

Le développement des pratiques de conservation de l'eau agricole est essentiel afin de limiter la sur-utilisation de l'eau agricole. Pour trouver un moyen efficace d'économiser l'eau dans la saison de la culture du blé, sans réduire nettement le rendement du blé, le modèle CropSyst de simulation a été calibré, validé et utilisé pour simuler l'utilisation de l'eau par le blé de printemps dans la plaine de Varamine. Lors de la saison de croissance 1980-2009, les autres saisons ont été déterminées comme étant sèche (1998-99), normale (1985-86) et humide (1997-1998). Le rendement du grain de blé a été simulé par CropSyst pour les différents scénarios déficitaires d'irrigation dans chaque saison de croissance. En utilisant l'Arc CS nous avons effectué une analyse spatiale de l'efficacité d'utilisation de l'eau. Pour cela, la météo régionale, le sol et la carte de la culture ont été préparés. Avec des logiciels GIS, ils ont été superposés et combinés afin d'obtenir une carte de simulation. Le scénario d'émissions A2 rapporté par l'IPCC a été utilisée. Ces données météorologiques ont été générées pour la période de 2011-2040 par le modèle ClimGen.

Les résultats montrent que dans la saison de pousse pluviale, la moyenne du rendement potentiel (7938 kg ha^{-1}) est plus élevée que dans la saison de pousse sèche (7725 kg ha^{-1}) et normale (6811 kg ha^{-1}). Les résultats montrent aussi que la productivité de l'eau dans la saison de pousse humide, normale et sèche à base de TR ont été 2,01 (ce qui se produit dans 50% des scénarios des besoins d'irrigation), 1,95 (40% IR) et 2 (40% IR) kg m^{-3}. Sur la base d'EH ils ont été de 1,5 (70% IR), 1,25 (80% IR) et 1,4 (70% IR) kg m m^{-3}. Sur la base d'eau, le profil du sol de l'eau entrant était 1,38 (50% IR), 1,04 (60% IR) et 1,2 (40% IR) kg m m^{-3}, respectivement. L'analyse de la condition du changement climatique a montré que la productivité moyenne de l'eau sur la base d'ET, de Tr et de l'eau entrant dans le profil du sol dans la période 2011-2040 ont diminué d'environ 13,78%, 1,62% et 9,04% a observé l'irrigation optimale dans les valeurs WUS dans la saison de croissance normale, respectivement.

Mots clés : *changement climatique, ClimeGen, modèle CropSyst, déficit d'irrigation, Varamin, blé.*

1. INTRODUCTION

The Varamin Plain is one of the most important agricultural production areas in Iran. It is located 40km south east of Tehran. The arable area is 600 Km^2 of which, more than about 200 Km^2 is occupied with wheat. The maximum temperature of the area is 44°C, during the summer and its annual range is 24°C. The average annual temperature is about 17°C and the annual rainfall and evaporation are 160mm and 2400mm, respectively. More precipitation falls during the winter and early spring months. Breaks in precipitation during the wheat growing season (October to June) leads to frequent and severe water stress. Therefore, it is necessary to develop optimal water management practices based on climatic conditions to avoid overuse of water resources, mitigate groundwater table decline and maintain a sustainable agricultural production. This requires knowledge of how crop yield and water use efficiency (WUE) are influenced by climate variability and irrigation management. Since the productivity of a cropping system under field conditions is influenced by soil type, climate and management practices and their interactions, it is important to have the detailed information of the individual effect of these variables on plant growth, grain yield and water use efficiency. To have such information from field experiments is costly and time consuming exercise. Crop growth simulation models are useful analytical tools to study the effects of climate, soil, and management on crop growth, grain yield and the environment. Crop simulation models are widely applied at large scale for climate change impact assessment or integrated assessment studies.

CropSyst is a multi-year and multi-crop daily time step simulation model (Stockle et al., 2003). Crop yield estimation may play a fundamental role in supporting policy, formulation and decision-making in agriculture. For example, if we can understand the role of climate forcing on yield in the past, present, and projected future changes, it will be helpful for establishing a warning system so that adaptations can be made at an early stage (Liu et al, 2010). Whereas elevated atmospheric CO_2 increases plant photosynthesis rates and thus crop yields (Kimball, 1983), GCM-predicted increases in temperature and related precipitation changes may also affect crop photosynthesis, plant development rates, as well as water and nutrient budgets in the field (Long, 1991). Ultimately, the net effects of increased CO_2 and climate change on crop yields will depend on local conditions. For example, warmer spring–summer air temperatures might be beneficial to crop yields at northern temperate latitudes, where the length of growing seasons could increase. However, increased temperatures would likely to be detrimental in Mediterranean-type environments, where high summer temperature and water stresses already limit crop production (Rosenzweig and Tubiello, 1997).

The objective of this paper is spatial and temporal assessment of wheat water use efficiency (WUE) in different deficit irrigation scenario in the Varamin plain, Iran. WUE was evaluated using observed and generated weather data covering wet, normal and dry growing season. The climate change condition in period (2011-2040) was considered, assuming that normal and traditional irrigation would be applied in future.

2. MATERIALS AND METHODS

The simulation model: CropSyst

CropSyst is a multi-year multi-crop simulation model developed to study the effect of cropping systems management on productivity and environment (Sto¨ckle and Nelson, 2000; Sto¨ckle et al., 2003). This model has been used to model the growth and development of several crops such as wheat, maize, barley, soybean and sorghum in the western USA, southern France, northern and southern Italy, northern Syria, northern Spain and western Australia with generally good results (Sto¨ckle, 1996). CropSyst has also been used to investigate potential impacts of climate change on crop production (e.g., Tubiello et al., 2000; Donatelli et al., 2003). It was also calibrated and validated for the site under study using 5 years of maize grain yield and phonological data (Abraha, 2003).The model consists of several integrated components and different management options. Details about components and uses can be found in the model user’s manual (Stockle and Nelson, 1993a) and elsewhere (Stockle et al., 1994).

Crop development and growth modeling

Crop development is determined as a function of thermal time required to reach specified growth stages, modulated by photoperiod and vernalization effects if applicable. Crop growth is determined by above-ground biomass accumulation, which is dependent on intercepted radiation converted to biomass (radiation-limited growth) (Monteith, 1977), transpiration (water-limited growth) and nitrogen uptake (nitrogen-dependent growth). Each of these factors is capable of limiting growth of plants. For this study, where the main objective was to quantify water-related agroclimatic indices, nitrogen limitations were not explicitly simulated, but played a role in the selection of other growth parameters so as to limit maximum attainable yields. The water-limited growth rate is calculated using the equation given by Tanner and Sinclair, (1983):

$$G_w = KT_{act}/VPD$$

where G_w is water-limited biomass production (kg m^{-2} day^{-1}), T_{act} is the actual transpiration (m day^{-1}), K is the above ground biomass transpiration coefficient (kg-kPa m^{-3}), and VPD is daily mean vapor pressure deficit (kPa).

Radiation-limited growth rate (G_r) (kg m^{-2} day^{-1}) is given by Monteith (1977):

$$G_r = efS_t$$

where e is a radiation conversion efficiency for the crop (kg MJ^{-1}), St is the total estimated daily solar radiation above the crop canopy (MJ m^{-2} day^{-1}), and f is the fraction of incident radiation intercepted by the canopy. The minimum of G_w and G_r defines the actual biomass growth for a given day. Leaf area index and root growth are related to biomass accumulation (Stockle and Nelson, 1993a; Stockle et al., 1994)

Input data requirements for CropSyst

The model simulates a single land block fragment. A land block fragment represents a biophysically homogeneous unit area with a uniform management regimen. Simulation scenarios for land block fragments are created by preparing parameter files describing the climate, soil, crops and crop management. A simulation control file identifies and links all the input files, provides initial conditions, selects optional simulation modules, and specifies the scenario to be simulated (Stockle et al., 2003). The input data sets needed for Cropsyst describe the location-weather, soil, crop and management practices.

Location-weather database

In Cropsyst, location-related parameters refer to information that is specific to the study site such as name, latitude, and daily weather database. Four weather stations covered the study area (Fig. 1a) that used in location-weather database. Each location-weather polygon referenced to a given weather station as an attribute of the polygon. To satisfy the need for the long-term daily weather records required by the model, the weather generator ClimGen was used. ClimGen (Stockle and Nelson, 1999; Stockle et al. 2001), a daily time step stochastic model, generates daily precipitation, minimum and maximum air temperatures, solar radiant density, atmospheric humidity and wind speed data series with similar statistics to that of the historical weather data. The model is based on historical data and is designed to preserve interdependence between variables as well as persistence and seasonal characteristics of each variable.

Soil database

Varamin plain had eight important soil types. Soil texture varied between sandy soil in north part of plain (Jajeroad series) to clay soil in south part of plain (Dolatabad series), Jajeroad river was the agent causing soil texture variation from light to heavy texture through transport and deposition of the river sediment. A parameter file was generated for each main soil type (Fig.1b). Each soil parameter file contained parameters such as number of soil layers, layer thickness (m), volumetric water content (m^3 m^{-3}) at permanent wilting point and field capacity, and bulk density (g cm^{-3}).

Rotation database

Rotation parameter file contain crop and management parameters in one file for each cropping system map's polygons. The polygons in the cropping system map will be associated with CropSyst rotation files. This map will be needed to specify different crop rotation or management practices i.e., different crops or management in different fields or study plots were represented in the map. In this study we obtained cropping system map by overlaying two maps. First map was the wheat calibration region map and second map was real arable area in Varamin plain that was obtained from Satellite image, IRS-P6 LISS III taken on 24 may 2008 (Fig.1c).

Crop database

In this study we calibrated CropSyst model in nine point of plain for spring wheat with 1-3 yearly separate farm experiment (Montazar et al., 1388 & Farshi and ghaemi., 1375 & Mollahosseini, 1385 & Varamin Agricultural Jehad Management Service (AJMS), 1382, 1384, 1384a, 1387, 1388 and 1388a) (Fig.1d). Then we had 9 crop parameter file. The crop file included parameters such as the thermal time requirements for given phonological events, the maximum root depth, the maximum leaf area index (LAI), the biomass-transpiration coefficient and other parameters. Most parameters were used as suggested in the model user's manual (Stockle and Nelson, 1993a).

Management database

CropSyst provides facilities for specifying the following management practices: irrigation, nitrogen, tillage, residue, clipping and soil conservation. The user may specify automatic and/or specific management events. For each biophysically homogeneous unit we had a management parameter file.

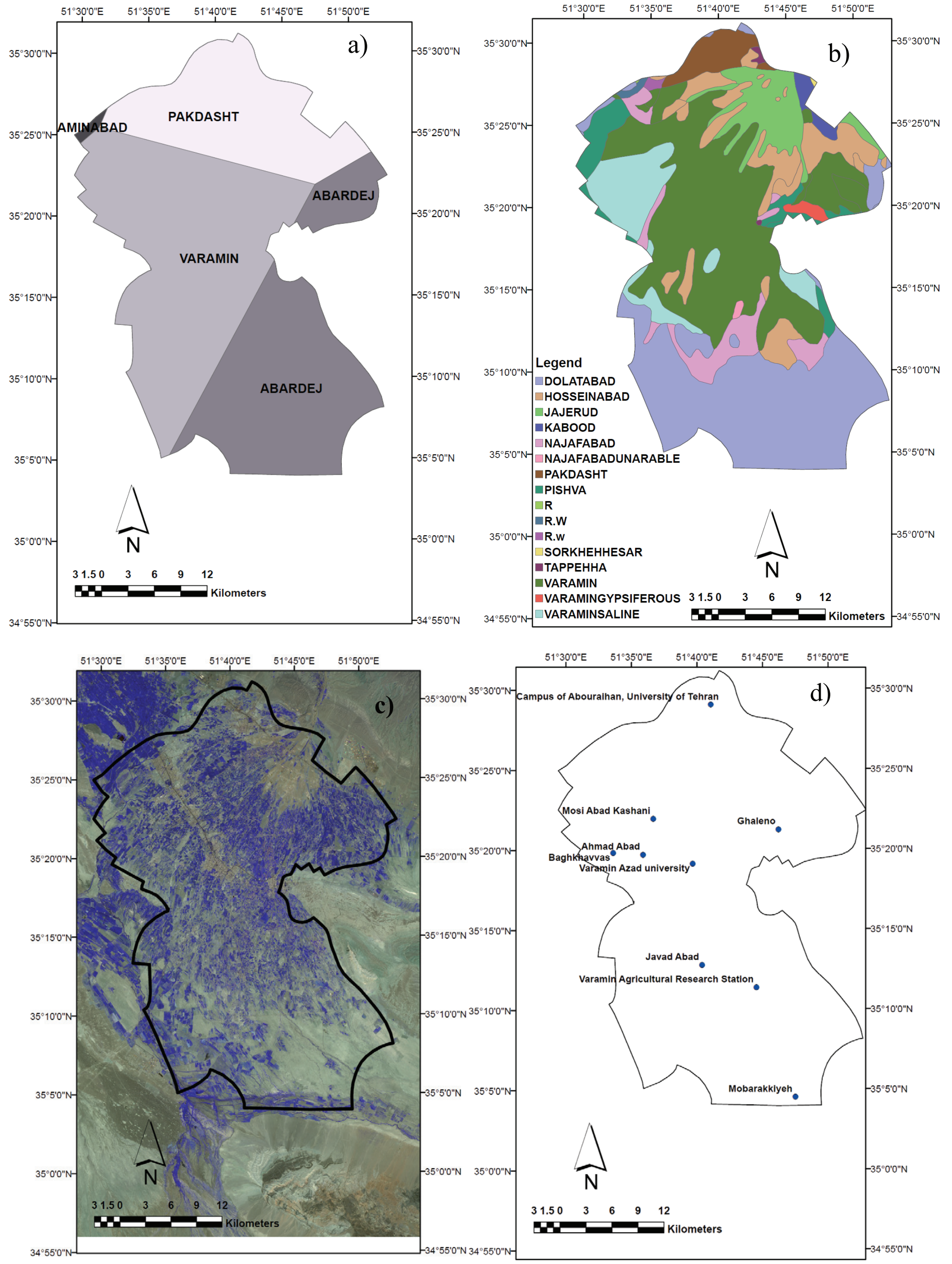

Fig.1. a) study area and weather regions that covered with four weather station, Varamin, Abardej, Aminabad and Pakdasht, b) soil map with eight main soil series and sub series, c) Satellite image, IRS-P6 LISS III that taken in 24 may 2008 and d) wheat calibration points in Varamin plain.

Combined simulation map

The combined simulation map obtained from union procedure of GIS software. We overlaid the three maps: weather-Location, soil and cropping system map. Each polygon number from each map was associated with the corresponding CropSyst (location-weather, soil and rotation) parameter files. This was accomplished by creating a simple attribute in polygon attribute table consisting of the polygon numbers and the corresponding parameter file names, which was used as input to the Arc CS-CropSyst Cooperator program (Stockle and Nelson, 1993b), which controls model execution and generates the simulation outputs.

Climate Change scenarios

The output of GCMs was used as weather input for a cropping system simulator, CropSyst. The Intergovernmental Panel on Climate Change (IPCC) released a special report on emissions scenarios (SRES) that grouped future greenhouse gas emission scenarios into four (i.e. A1, A2, B1 and B2) separate “families” that depend upon future developments in demography, economic development, and technological change. In this paper we used A2 scenario (Table, 1) and then Weather data were generated for the period of 2011-2040 by the calibrated ClimGen model. 30-yearly data set of daily weather records (1980–2009) for each four weather station covering study area include Varamin, Abardej, Aminabad and Pakdasht was used as a base line weather data (Fig.1). The future scenario data were provided with consisted of multipliers for future years (or months in years). ClimGen generates historical data value (like normal), but applies the respective multipliers for the respective future year and/or month that the generated data falls in.

Model simulations

At first, CropSyst was calibrated at 9 points of the plain. Campus Aboureihan, University of Tehran and Varamin Agricultural research Station experiments had conducted 3-year experiments and in these experiments, data on phonological stage were observed and recorded. We used these two points for validation. The calibrated CropSyst model was used to simulate the grain yield of wheat for different deficit irrigation scenarios (i.e. 40, 50, 60, 70, 80 and 90 percent of crop water demand and complete irrigation), in three different growing season, i.e. dry (1998-99), normal (1985-86) and wet (1997-98). Climate change scenarios for each station generated using ClimGen by considering, GCM output and A2 scenario climate change rates. The ClimGen output files were used as a CropSyst model inputs. Cropsyst simulated wheat grain yield, above biomass, transpiration, evapotranspiration and sum of irrigation and effective precipitation. Water use efficiency with the base of transpiration, evapotranspiration and water entering soil profile (Irrigation and effective precipitation) was calculated.

Table 1. Some aspects of the SRES emissions scenarios and their implications for carbon dioxide (CO_2) concentration, global temperature and sea-level rise by 2050. Data in columns 2-4 are taken from Nakicenovic et al. (2000). ΔT is change in mean annual temperature averaged across simple climate model runs emulating the results of seven AOGCMs with an average climate sensitivity of 2.8°C. CO_2 concentrations were estimated using the same model runs. Sea-level rise estimates are based on the temperature changes (Source: Carter et al., 2001).

Emissions scenario	Global population (billions)	Global GDP[1] (10^{12} US\$ a^{-1})	Per capita income ratio[2]	CO_2 concentration (ppm)	Global ΔT (°C)	Global sea-level rise (cm)
1990	5.3	21	16.1	354	0	0
2000	6.1-6.2[3]	25-28[3]	12.3-14.2[3]	367[3]	0.2	2
2050						
SRES A1FI	8.7	164	2.8	573	1.9	17
SRESA1B	8.7	181	2.8	536	1.6	17
SRES A1T	8.7	187	2.8	502	1.7	18
SRESA2	11.3	82	6.6	536	1.4	16
SRESB1	8.7	136	3.6	491	1.2	15
SRESB2	9.3	110	4	478	1.4	16

3. RESULTS AND DISCUSSION

Calibration

We calibrated spring wheat in 9 points of varamin plain as shown in Fig.1d (i.e. Campus of Abouraihan, University of Tehran (CAUT), Varamin Agricultural Research Station (VARS), Ghaleno, Mosi Abade Kashani, Bagh khavvas, Ahmad Abad, Varamin Islamic Azad University, Javad Abad and Mobarrakiyeh). Calibrated crop model parameters are shown in Table 2.

Table 2. Calibrated crop parameters for spring wheat in Varamin plain for each study point.

Parameters	Unit	CAUT	VARS	Ghaleno	Mosi Abad	Bagh Khavvas	Ahmad Abad	VIAU	Javad Abad	Mobara-kiyeh
Canopy extinction coefficient for total solar radiation	-	0.51	0.53	0.5	0.51	0.55	0.53	0.55	0.53	0.53
Evapotranspiration crop coefficient at full canopy	-	1.1	1.15	1.05	1.15	1.15	1.15	1.15	1.15	1.15
Maximum water Uptake	(mmd^{-1})	13.5	13	13	13.5	13	13	13	13	13
Above ground biomass transpiration coefficient	(Pa)	6.4	6.63	6.35	6.5	6.63	6.63	6.63	6.63	6.63
Maximum root Depth	(°C-d)	1200	1040	1040	1200	1140	1040	1140	1040	1200
Maximum rooting depth	(m)	1.6	1.64	1.64	1.7	1.7	1.65	1.7	1.65	1.64
Leaf area Duration	(°C-d)	950	1000	1000	1000	1000	1000	1000	1000	1000
Nitrogen demand adjustments	-	0.56	0.54	0.6	0.5	0.5	0.54	0.5	0.54	0.5
Maximum nitrogen uptake during rapid linear growth	($Kg\ ha^{-1}\ day^{-1}$)	7	6	8.1	8	9	8.1	9	8	8
Unstressed HI	-	0.42	0.33	0.38	0.38	0.4	0.42	0.4	0.4	0.38

Validation

The results, presented in Table 3, are expressed as average observed and simulated wheat grain yields in two points of plain (i.e. Campus of Abouraihan, University of Tehran and Varamin Agricultural Research Station). The model produced both over- and under-estimates. Before any model can be used with confidence, adequate validation or assessment of the magnitude of the errors that may result from their use should be performed. In this study CropSyst model was validated by comparison between simulated and observed grain yield values. Besides the above comparisons for validation of the model, there are several statistical measures available to evaluate the association between predicted and observed values. One mostly used among is the test of the significance of regression and the coefficient of determination (R^2). Table 3 gives the result of adopting this method for an assued linear regression between the observed and the simulated grain yield values. The difference measures include the mean absolute error (MAE) and the root mean square error (RMSE). RMSE and MAE are the best measures of model performance evaluation as they summarize the mean difference in the units of observed and predicted value. d is Index of agreement. A value of d of 1.0 indicates excellent agreement.

Table 3. Statistical summary comparing measured and simulated grain yields

Calibration point	Observed average	Simulated average	n	a	b	MAE (Kg ha^{-1})	RMSE (Kg ha^{-1})	d	R^2
VARS	6875.7	6856	12	0.961	273.3	256.76	284.28	0.92	0.76
CAUT	4829.13	4838.26	36	0.945	271.2	155.26	190.08	0.99	0.98

The generated weather data set of 30-year (1980-2009) was compared with the observed weather data for same period in Varamin Weather Station in Table 4. The results show that the ClimGen predictions are acceptable. In the other word, the stochastic weather generator used in this study may be used in the simulation of different weather statistics, including those climatic extremes relevant to agriculture.

Table 4. Comparison of observed and generated average daily weather data (1980-2009) for Varamin weather station.

Parameter	mean (estimated)	mean (actual)	RMSE	d	R^2
Precipitation[1] (mm)	0.4263	0.3975	0.0749	0.9949	0.956
Max t (^{0}C)	32.23	30.49	2.89	0.974	0.995
min t (^{o}C)	2.83	2.67	0.32	0.973	0.901
Srad (Mj m^{-2})	18.29	18.62	0.77	0.996	0.998

1-For precipitation 30 daily moving average considered.

Wheat grain yield in different deficit irrigation scenarios

As shown in Fig.2, Wheat grain yield increased with increasing irrigation amount until complete irrigation demand. In this study we hadn't any nitrogen limitation during wheat growing season. The result show that in the wet growing season the potential yield average (7938 kg ha^{-1}) is higher than dry (7725 kg ha^{-1}) and normal (6811 kg ha^{-1}) growing season. This values are regional average and wheat yield varied about 3180- 9845, 2418-10190 and 1696- 9095 kg ha^{-1} in wet, dry and normal seasons throughout plain. This show that wheat potential yield is higher in dry season but water shortage may be reduce growing season duration and total incident radiation in dry season become less than wet season.

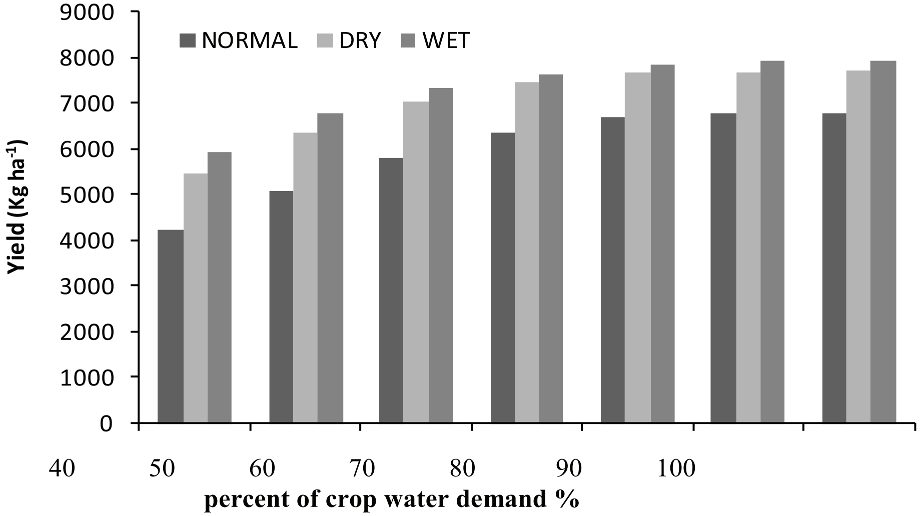

Fig 2. Average wheat grain yield in different irrigation scenarios in three different growing season condition i.e. wet, dry and normal.

Wheat water use efficiency

Water use efficiency (WUE) can be used for choice optimal water management strategies for spring wheat in the Varamin plain for the purpose of more efficient use of the limited water resources. Result showed that maximum mean WUS in plain occurred in deficit irrigation (table. 5). For example in dry season only with 40% wheat complete irrigation requirement we achieved max regional mean WUS_{I+Re}. In dry season when we applied deficit irrigation from 60% (40%IR) to 10% (90%IR) and complete irrigation, the WUS_{I+Re} varied between 0.46-1.7 Kg m^{-3} throughout Varamin plain.

Table 5. highest values of three WUS index in wet, dry and normal growing season condition in Varamin plain.

Base of calculated WUE	Growing season condition	Irrigation scenario %	Regional average WUE (Kg m^{-3})	Range (Kg m^{-3})	Standard deviation (Kg m^{-3})
Transpiration	WET	50	2.01	1.69-2.31	0.14
	NORMAL	40	1.95	1.33-2.76	0.35
	DRY	40	2	1.43-2.32	0.13
Evapotranspiration	WET	70	1.5	1.2-1.74	0.11
	NORMAL	80	1.25	0.83-1.51	0.19
	DRY	70	1.4	1.07-1.63	0.11
Irrigation and effective precipitation	WET	40	1.38	0.57-1.94	0.35
	NORMAL	60	1.04	0.55-1.42	0.23
	DRY	50	1.2	0.46-1.7	0.33

Spatial and temporal distribution of wheat WUS_{I+Re}

Fig 3. Show spatial and temporal distribution of wheat water use efficiency on base sum of irrigation and effective precipitation WUS_{I+Re} in complete irrigation scenario. When complete irrigation applied, more WUS_{I+Re} achieved in wet, normal and dry season, respectively. In dry season, because air aridity exists then crop transpiration demand is high, as crop needed more volume of irrigation water for specific level of grain yield. Thus WUS_{I+Re} became smaller in dry

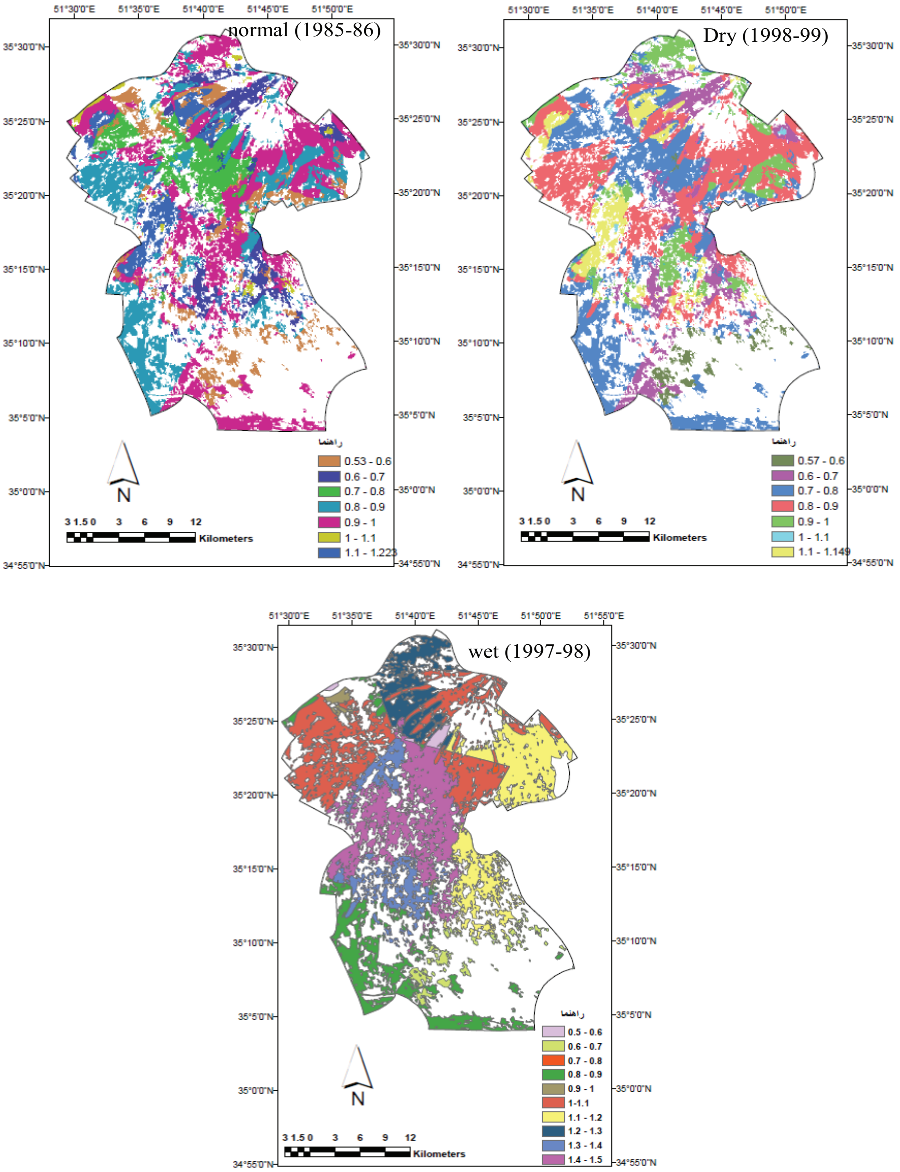

Fig 3. Spatial and temporal distribution of wheat WUS_{I+Re} (Kg m^{-3}) in complete irrigation scenario at Varamin plain.

season, however potential grain yield in this season was high. Results show that soil water holding capacity played a key role in WUS_{I+Re} amount. In middle part of plain soil texture is clay loam (Varamin soil series) and have greater water holding capacity then WUS_{I+Re} had a high values in this part than north part of plain that had a sandy texture soil (Jajeroad soil series).

Wheat WUS variation in climate change condition

With assuming that in future, people fallowed region conventional irrigation scheme, as shown in fig. 4. Variation of average WUS on base of transpiration (Tr), evapotranspiration (ET) and sum of irrigation and effective precipitation ($I+R_e$) in period 2011-2040 had same behavior. But WUS_{I+Re} had great impressibility under climate change condition. The WUS analysis in climate change condition showed that average water productivity on base of ET, Tr and I+Re in period 2011-2040 was 1.68, 1.23 and 0.946 kg m^{-3}, respectively (table.6) and decreased about 13.78, 1.62 and 9.04 % observed optimum irrigation scenarios in normal growing season WUS values, respectively.

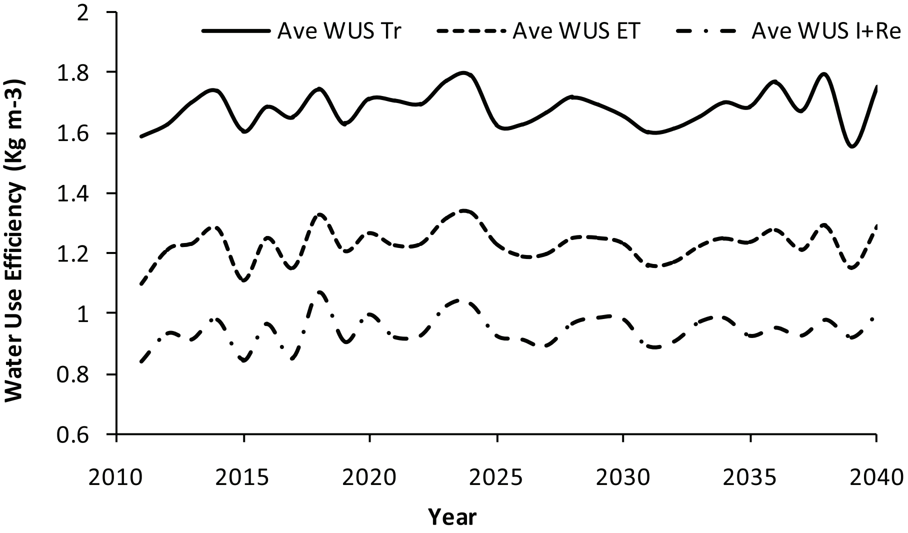

Fig 4. Variation of average WUS (kg m^{-3}) on base of transpiration (Tr), evapotranspiration (ET) and sum of irrigation and effective precipitation ($I+R_e$) under climate change condition in period 2011-2040

Table 6. Average, Max and min water use efficiency on base of ET, Tr and I+Re in period 2011-2040 under climate change condition.

parameter	average	Max	min
WUE Tr	1.68	2.22	0.899
WUE ET	1.23	1.74	0.25
WUE I+Re	0.946	1.426	0.426

4. CONCLUSIONS

Outcomes of this study confirm CropSyst capability in simulating climate, environmental and irrigation strategies, therefore we suggest implementing of CropSyst in arid and semi arid region.

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