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Simulating water productivity of paddy rice under irrigation regimes using AquaCrop model in humid and semiarid regions of Iran

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Abstract

Rice production in the world is heavily dependent on water. Therefore, increasing in water productivity with appropriate irrigation management is necessary. Simulation models that illustrate the effects of water on crop growth can apply to optimize water productivity and improve farm irrigation management. This study was conducted to simulate water productivity of paddy rice using AquaCrop model in both humid and semiarid regions of Iran. Required data for running model were gained from two field experiments: an experiment with a lowland local rice cultivar named *Champa-Kamfiroozi* in a semiarid climate (Kooshkak), and other experiment with two lowland local rice cultivars named *Binam* and *Hasani* in a humid climate (Rasht). Both experiments were conducted under five irrigation treatments in two consecutive years. As a result, the relative root mean square error (RRMSE) of grain yield simulation was gained between 2.28 and 15.09%. The ranges of water productivity based on transpiration (WP_T) and water productivity based on evapotranspiration (WP_{ET}) as affected by irrigation treatments, in dry climate were greater than wet climate. The averages of WP_T and WP_{ET} for continuous flooding in the humid (1.21 and 0.82 kg m^{-3}, respectively) and dry (1.26 and 0.76 kg m^{-3}, respectively) climates showed the role of evaporation losses in decreasing WP in dry climate. The highest ET was obtained in continuous flooding treatments that the amount of evaporation for dry climate was 88% higher than humid climate.

Keywords AquaCrop · Kooshkak · Rasht · Rice yield

Introduction

Water demand growth in urban, industrial, recreational and environmental purposes creates more competition for the limited resources. Therefore, to achieve a food security and sustainable agriculture in the future, increasing water productivity is necessary. Rice as a major crop is now grown in some provinces of Iran. The fraction of paddy fields area from cultivated lands in Guilan, Mazandaran and Fars provinces is about 52, 16 and 3%, respectively, and less than 1% in other parts of the country. Guilan and Fars provinces with humid and semiarid climates are located in north and south of Iran, respectively (Fig. 1). Conventional rice irrigation method in Iran is the continuous flooding during growing

season. Drought is a problem in these areas, spatially, in southern provinces and water is the most important factor in sustainable rice production. Therefore, increasing in water productivity with appropriate irrigation management is necessary. To achieve this goal, the plant growth simulation models can be used as a tool.

Crop models are used as decision support tools for increasing efficiency of planning and management of crop production processes (e.g. Farshi et al. 1987; Pang and Letey 1998; Pirmoradian and Sepaskhah 2006; Zand-Parsa et al. 2006). In practice, optimal scheduling of irrigation requires a good understanding of crop response to water deficit. The FAO AquaCrop model as a crop water productivity simulation model, represents the yield response to water using a few parameters and other input data (Steduto et al. 2009). AquaCrop model has been tested by several researchers for different crops and climates (Heng et al. 2009; Geerts et al. 2009; Baumhardt et al. 2009; Farahani et al. 2009; Hsiao et al. 2009; Todorovic et al. 2009; Araya et al. 2010a, b; Stricevic et al. 2011; Zinyengere et al. 2011; Zeleke et al. 2011; Mkhabela and Bullock 2012).

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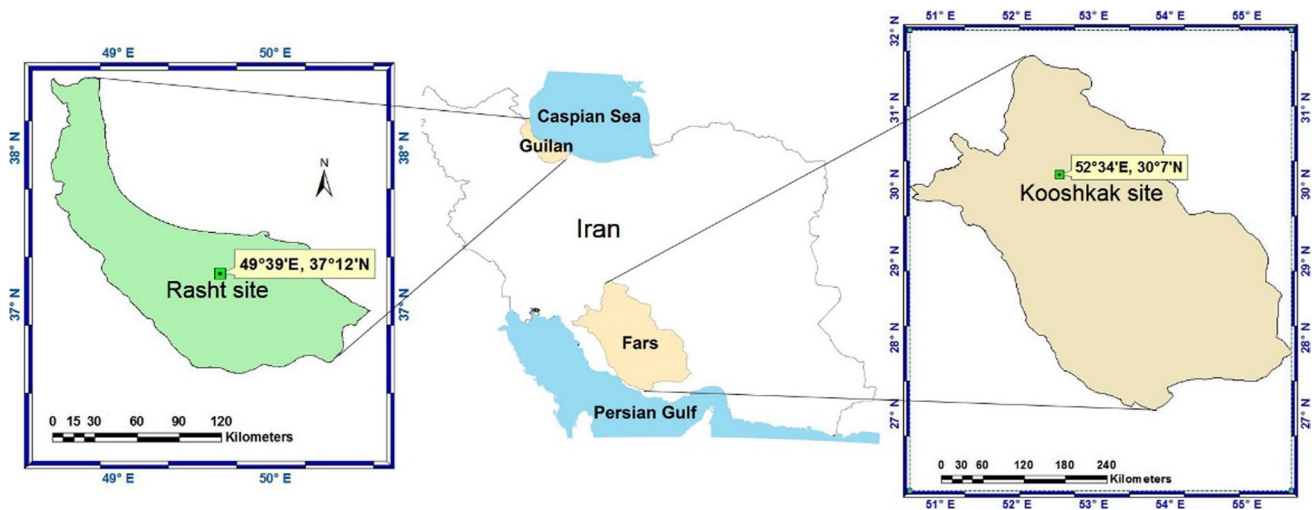
Fig. 1 Geographical positions of the experimental sites

Some researchers have been used the AquaCrop model to simulate rice yield response to water (Saadati et al. 2011; Lin et al. 2012; Shrestha et al. 2013; Maniruzzaman et al. 2015; Sandhu et al. 2015). Achieving an optimal irrigation schedule with the goal of maximum water productivity is especially important in terms of water scarcity in arid and semiarid areas, and even in a humid region. In addition, the water consumption and yield of paddy fields are directly affected by the climatic conditions and irrigation management. Therefore, the AquaCrop model can simulate the effects of climate conditions and irrigation managements on water productivity. Improvement of irrigation management can be achieved according to the results of simulating different management scenarios and their effects on water productivity. The objective of this study was to simulate water productivity of irrigated paddy rice using AquaCrop model in two different climates of Iran, Kooshkak in south of Iran as a semiarid region and Rasht in north of Iran as a humid region (Fig. 1).

Method

Data collection

The required data to simulate were obtained from the experiments described by Pirmoradian et al. (2004) and Rezaei and Nahvi (2007).

The first experiment (Pirmoradian et al. 2004) was conducted at Kooshkak Agricultural Research Station of Shiraz University (Lat. 30° 7′ N; Long. 52° 34′ E; Elevation of 1650 m.) on a clay loam soil during two consecutive growing seasons of 2000 and 2001. The experimental site was the irrigated area of Doroodzan Irrigation District located in Fars province at the south of Iran. Daily weather data included temperature, relative humidity, sunshine hours, wind speed and rainfall, were obtained from Koshkak meteorological station at the experimental site. The experiment was conducted with four replications. The treatments consisted of five irrigation regimes: (1) sprinkler irrigation with applied water equal to crop potential evapotranspiration, ET_p, (2) sprinkler irrigation with applied water equal to $1.5ET_p$, (3) continuous flooding irrigation, (4) intermittent flooding irrigation at 1-day interval, and (5) intermittent flooding irrigation at 2-day interval. Land preparation was done from 8 to 10 July in 2000 and from 28 to 30 June in 2001. There was transplanted a local cultivar (*Champa-Kamfiroozi*) of rice seedlings with 16 hills m^{-2} for 11 of July 2000, and with 25 hills m^{-2} for 1 of July 2001. In each plot, a sample area of 1 m^2 was used for measuring LAI at 7-day interval during the growing season.

The second experiment (Rezaei and Nahvi 2007) was conducted at Rice Research Institute of Iran, Rasht (Lat. 37° 12′ N; Long. 49° 39′ E; Elevation of 24.6 m) on a silty clay soil, during two consecutive growing seasons of 2003 and 2004. This experimental site is located in the north of Iran. This experiment was conducted on two local cultivars (*Binam* and *Hasani*) of lowland rice with five irrigation treatments consisted of: (1) continuous flooding irrigation, (2) irrigation immediately after disappearance of water from the soil surface, (3) irrigation at 3 days after disappearance of water from the soil surface, (4) irrigation at 6 days after disappearance of water from the soil surface, and (5) irrigation at 9 days after disappearance of water from the soil surface. Rice seedlings were transplanted with 25 hills m^{-2} on 27th and 9th of May in 2003 and 2004, respectively.

Climate and soil parameters of the experimental sites are shown in Tables 1 and 2, respectively. Based on the long

Table 1 Means of climate parameters during growing season for the experimental sites

Climate parameters	Kooshkak		Rasht			
	2000	2001	2003		2004	
	Champa-Kamfi-roozi		Binam	Hasani	Binam	Hasani
Shortwave radiation (MJ m^{-2} day^{-1})	27.0	27.3	26.04	26.23	26.07	25.84
Mean daily of min. temp. (°C)	14.2	16.2	19.4	19.4	18.7	18.7
Mean daily of max. temp. (°C)	33.7	36.4	28.3	28.2	27.5	27.3
Relative humidity (%)	32.5	28.7	76	76.05	78.6	78.9
Evaporation (mm)	1047	1188	316	300.2	309.1	291.8
Precipitation (mm)	0	0	130.1	127.2	317	317

Table 2 Soil parameters of the experimental sites

Soil parameters	Kooshkak		Rasht	
Sampling depth (cm)	0–30	30–60	0–30	30–60
Sand (%)	30	25	13.33	10
Silt (%)	39	32	40.67	42
Clay (%)	31	43	46	48
EC (dS m^{-1})	1.4	1.1	1.11	1.11
pH	7.1	6.9	7.21	7
Total nitrogen (%)	0.035	0.033	0.171	0.171
θ_s (Vol%)	50	55	54	55
θ_{FC} (Vol%)	39	54	50	54
θ_{PWP} (Vol%)	23	39	32	39
K_s (mm day^{-1})	100	2	15	2

period (40 years) of meteorological data and according to Demartone method, the climate of Kooshkak and Rasht sites were obtained as semiarid and very humid, respectively.

To establish the seedlings in both experiments, all of the treatments were irrigated with continuous flooding for the first 10 days. The delivered water to each plot was measured using a volumetric counter. Yield samples for grain and biomass were harvested from a 1×1 m area at the end of the growing season in the middle of the plots. Samples were air-dried for 5 days before being oven dried at 70 °C for 48 h. The amounts of applied irrigation water during the growing seasons at the different treatments are shown in Table 3.

FAO Penman–Monteith method (Allen et al. 1998) using the ET$_o$ Calculator software (FAO 2009) was used to compute daily reference evapotranspiration (ET$_o$) of experimental sites for the growing seasons. To calculate the canopy cover according to measured LAI values, the Eq. (1) was used (Ritchie 1972; Belmans et al. 1983; Ritchie et al. 1985):

$$CC = 1 - \exp^{(-K*LAI)}, \tag{1}$$

where CC is canopy cover, K is extinction coefficient that for rice are between 0.4 and 0.7 (Hay and Walker 1989), and LAI is leaf area index.

Model description

AquaCrop describes waterway through soil-crop-atmosphere to simulate crop growth and its response to water stress. In this way, it considers atmospheric data, crop conditions and field management practices (Raes et al. 2009a; Steduto et al. 2009). AquaCrop simulates canopy cover in a daily time scale. It also calculates crop evapotranspiration (ET) base on a daily soil water balance and separates it into transpiration (T) and evaporation (E) proportional to covered and uncovered parts of soil. The daily biomass production of the crop is calculated using a normalized crop water productivity (WP*) and a proportion of T/ET (Hsiao et al. 2009; Steduto et al. 2009). WP* is a fixed value for a given climate and crop and varies between 15 and 20 gm^{-2} for C$_3$ crops like rice (Raes et al. 2009b). Four stress coefficients related to leaf expansion, stomata closure, canopy

Table 3 Amounts of applied irrigation water (mm) during the growing seasons

Site	Year	Cultivar	Treatment				
			I1	I2	I3	I4	I5
Kooshkak	2000	Champa-Kamfi-roozi	835	1183	1984	1531	1258
	2001		971	1365	2266	1777	1445
Rasht	2003	Binam	477	363	394	238	289
		Hasani	444	489	352	498	313
	2004	Binam	249	194	209	118	87
		Hasani	279	239	112	52	118

senescence, and change in harvest index are used to consider the effect of water stress on biomass and yield productions.

Model calibration

The model was calibrated using the measured data during growing season of 2000 and 2003 in Kooshkak and Rasht sites, respectively. The calibrated parameters in the model are shown in Table 4. The conservative parameters were used as suggested by Raes et al. (2009b).

Criteria of model validation

For both experiments, the first year data set was used to calibrate the model and validation was done using independent data sets of the cropping seasons of the second year data set. The model validation was conducted using the coefficient of residual mass (C_{RM}), relative root mean square error (RRMSE) and model efficiency (ME) criteria as follows:

$$C_{RM} = \frac{\left[\sum_{i=1}^{n} O_i - \sum_{i=1}^{n} S_i\right]}{\sum_{i=1}^{n} O_i} \quad (2)$$

$$RRMSE = \left[1/n \sum_{i=1}^{n} \left(S_i - O_i\right)^2\right]^{0.5} \left(\frac{100}{MO}\right) \quad (3)$$

$$ME = \frac{\sum_{i=1}^{n} \left(O_i - MO\right)^2 - \sum_{i=1}^{n} \left(S_i - O_i\right)^2}{\sum_{i=1}^{n} \left(O_i - MO\right)^2}, \quad (4)$$

where S_i and O_i are simulated and observed values, respectively, MO is the mean of observed values and n is the number of observations. Values of the C_{RM} and RRMSE close to zero represent the better quality of simulation. In addition, ME varies from negative infinity to positive 1, and values closer to 1 show the more ability of the model.

Results

The ME, RRMSE and C_{RM} for canopy cover simulation are presented in Table 5. As a result, the amounts of ME in canopy cover simulation for different irrigation treatments were obtained from 0.74 to 0.83. C_{RM} were gained from −0.005 to 0.037 and RRMSE were ranged to 13.1–16.4%. RRMSE in rice LAI simulation using WOFOST model varied between 54 and 83% according to Amiri et al. (2011), while other studies reported RRMSE values on simulating of maize canopy cover using AquaCrop between 5.85 and 13.59% (Hsiao et al. 2009) and from 5.06 to 34.53% (Heng et al. 2009). A strong linear relationship between simulated and observed canopy cover in simulating biomass and yield of barley was reported by Araya et al. (2010a), ($r^2 > 0.92$). Maniruzzaman et al. (2015) reported $7.6 < NRMSE < 14.3$

Table 4 Amounts of the AquaCrop model calibrated parameters to simulate rice growth and yield

Description	Cultivar		
	B	*H*	Ch-K
Initial canopy cover (%)	1.25	1.25	0.48
Plant density (plants ha^{-1})	250,000	250,000	160,000
Days from transplanting to recovered transplant	7	7	7
Days from transplanting to maximum canopy cover	47	41	50
Days from transplanting to start of canopy senescence	75	75	75
Days from transplanting to maturity	95	91	95
Maximum effective rooting depth (m)	0.35	0.35	0.4

B, Binam; H, Hasani; Ch-K, Champa-Kamfiroozi

Table 5 Amounts of ME, RRMSE and C_{RM} of canopy cover simulation for different irrigation treatments in Kooshkak

Treatment	2000			2001		
	ME	RRMSE (%)	C_{RM}	ME	RRMSE (%)	C_{RM}
Sprinkler (1*ETp)	0.8	16.2	−0.012	0.82	13.6	0.015
Sprinkler (1.5*ETp)	0.76	16.1	−0.007	0.82	13.3	0.033
Continuous flooding	0.74	16.4	−0.005	0.83	13.2	0.026
Intermittent fl. (1-d. Int.)[a]	0.75	16.4	−0.012	0.81	13.7	0.028
Intermittent fl. (2-d. Int.)[b]	0.75	16.3	−0.005	0.80	13.9	0.037

[a]Intermittent flooding (1-day interval)

[b]Intermittent flooding (2-day interval)

for simulating rice canopy cover using AquaCrop. In comparison, the AquaCrop model showed a good simulation for rice canopy cover in this study.

The values of ME, RRMSE and C_{RM} for yield and biomass simulations in Kooshkak site and for yield simulations in Rasht site are shown in Tables 6 and 7, respectively. The model simulation results show better performance for grain yield than biomass. In addition, the validation results were better for *Binam* cultivar than *Hasani* and *Champa-Kamfiroozi* cultivars. Based on RRMSE, Aquacrop has simulated rice yield better for humid climate than semiarid climate. AquaCrop model is validated for some specific plants in simulating of biomass and yield. In Confalonieri and Bocchi (2005) on evaluation of CropSyst for simulating of flooded rice, ranges of RRMSE in the biomass simulation for calibration and validation processes were obtained from 11 to 29% and from 10 to 52%, respectively and ranges of C_{RM} in biomass simulation for calibration and validation processes were obtained from −0.03 to 0.17 and from −0.02 to 0.17, respectively. In case of simulating paddy rice growth using AquaCrop, Saadati et al. (2011) reported that the RMSE was 0.7 t ha^{-1} for simulating grain yield in the validation process. Shrestha et al. (2013) reported RMSE of 0.2 t ha^{-1} for grain yield simulation. Sandhu et al. (2015) reported RRMSE of 15.54% in simulating biomass. Maniruzzaman et al. (2015) presented $10.0 \leq NRMSE \leq 14.7$ for biomass simulation. Accordingly, the results showed that the AquaCrop model could simulate yield and biomass of rice in both humid and semiarid regions.

According to Table 6, for Kooshkak site, the values of ME and RRMSE show a better simulation for grain yield than biomass. Similar results were observed in Araya et al. (2010a) study on simulating biomass and yield of barley that ME values for biomass and grain yield simulations were obtained from 0.53 to 1 and from 0.5 to 0.95 and RMSE values were obtained from 0.36 to 0.9 t ha^{-1} and from 0.07 to 0.27 t ha^{-1}, respectively. In addition, in Araya et al. (2010b) on simulating of Teff growth, RMSE values were obtained from 0.2 to 0.92 t ha^{-1} and from 0.05 to 0.21 t ha^{-1}, respectively. In Heng et al. (2009) to simulate maize using AquaCrop model, RMSE values for biomass and grain yield simulations were obtained from 0.46 to 6.51 t ha^{-1} and from 0.65 to 1.57 t ha^{-1}, respectively. In García-Vila et al. (2009) to manage of Cotton irrigation with AquaCrop, RMSE of grain yield and biomass simulations were obtained 0.72 and 1.01 t ha^{-1}, respectively. Due to Todorovic et al. (2009) on assessment of AquaCrop, CropSyst, and WOFOST models in simulating of Sunflower growth, RMSE values for final biomass simulation for these models were obtained 1.81, 2.49 and 2.95 Mg ha^{-1}, respectively and for final grain yield simulation were obtained 0.7, 0.94 and 0.79 Mg ha^{-1}, respectively. Therefore, these comparisons showed that the AquaCrop model had a good simulation for rice yield and biomass.

Based on the simulation results, the amounts of evaporation, transpiration and water productivity based on transpiration (WP_T) and evapotranspiration (WP_{ET}) in different irrigation treatments for the experimental sites are presented in Table 8. The amounts of evaporation varied from 214.2 to 237.8 mm with an average of 227.7 mm in Kooshkak site for different treatments. These values were 103 to 135.2 mm with an average of 117.5 mm in Rasht. ET ranged from 470.2 to 624.9 mm in Kooshkak and 324.6–386 mm in Rasht for different treatments. The values of WP_T were gained from 0.71 to 1.38 kg m^{-3} in Kooshkak and from 1.11 to 1.31 kg m^{-3} in Rasht. The ranges of WP_{ET} were obtained as 0.37–0.83 and 0.74–0.92 kg m^{-3} in Kooshkak and Rasht, respectively. As shown, the ranges of WP_T and WP_{ET} as affected by irrigation treatments, in dry climate (Kooshkak) are greater than wet climate (Rasht). WP_T depends on crop types and varieties. The averages of WP_T in continuous flooding treatments over two consecutive years were gained 1.26, 1.27 and 1.15 kg m^{-3} for *Champa-Kamfiroozi*, *Binam* and

Table 6 Amounts of ME, RRMSE and C_{RM} for biomass and yield simulations in Kooshkak

Region	Year	Cultivar	Biomass			Yield		
			ME	RRMSE (%)	C_{RM}	ME	RRMSE (%)	C_{RM}
Kooshkak	2000	Champa-Kamfiroozi	0.94	18.34	0.18	0.99	3.29	−0.02
	2001		0.25	11.59	0.06	0.37	15.09	0.13

Table 7 Amounts of ME, RRMSE and C_{RM} for yield simulation in Rasht

Region	Cultivar	Yield					
		2003			2004		
		ME	RRMSE (%)	C_{RM}	ME	RRMSE (%)	C_{RM}
Rasht	Binam	0.72	6.73	−0.03	0.95	2.28	0.014
	Hasani	0.52	5.48	0.016	0.65	10.92	−0.07

Table 8 Values of evaporation (E), transpiration (T) and water productivity based on transpiration (WP_T) and evapotranspiration (WP_{ET}) for different irrigation treatments for both experimental sites

Site	Year	Cultivar	Treatment	E (mm)	T (mm)	WP_T (kg m^{-3})	WP_{ET} (kg m^{-3})
Kooshkak	2000	Champa-Kamfiroozi	Sprinkler (1*ETp)	226.3	243.9	0.71	0.37
			Sprinkler (1.5*ETp)	228.8	242.1	1.01	0.52
			Continuous flooding	226.4	307.1	1.21	0.70
			Intermittent fl. (1d. Int.)[a]	224.9	254.2	1.21	0.64
			Intermittent fl. (2d. Int.)[b]	214.2	259.3	1.38	0.76
Kooshkak	2001	Champa-Kamfiroozi	Sprinkler (1*ETp)	234.8	386.8	0.82	0.51
			Sprinkler (1.5*ETp)	237.8	383.5	1.12	0.69
			Continuous flooding	231.4	393.5	1.31	0.82
			Intermittent fl. (1d. Int.)[a]	232.2	386.8	1.34	0.83
			Intermittent fl. (2d. Int.)[b]	220.5	386.8	1.35	0.80
Rasht	2003	Binam	Continuous flooding	134.1	251.9	1.23	0.80
			Irrigation (Im. After Dis. W.)[c]	129.9	251.8	1.23	0.81
			Irrigation (3d. After Dis. W.)[d]	132.6	251.9	1.23	0.81
			Irrigation (6d. After Dis. W.)[e]	135.2	189.4	1.31	0.76
			Irrigation (9d. After Dis. W.)[f]	128.7	241.3	1.23	0.80
Rasht	2003	Hasani	Continuous flooding	118.9	243.3	1.11	0.75
			Irrigation (Im. After Dis. W.)[c]	118.9	243.3	1.11	0.75
			Irrigation (3d. After Dis. W.)[d]	118.9	243.3	1.11	0.75
			Irrigation (6d. After Dis. W.)[e]	118.9	242.5	1.11	0.74
			Irrigation (9d. After Dis. W.)[f]	120.1	234.8	1.17	0.78
Rasht	2004	Binam	Continuous flooding	124.9	256.6	1.31	0.88
			Irrigation (Im. After Dis. W.)[c]	111.9	254.7	1.31	0.91
			Irrigation (3d. After Dis. W.)[d]	109.5	253.9	1.31	0.92
			Irrigation (6d. After Dis. W.)[e]	107.8	252.6	1.31	0.92
			Irrigation (9d. After Dis. W.)[f]	104.4	241.6	1.31	0.92
Rasht	2004	Hasani	Continuous flooding	110.2	249.3	1.20	0.84
			Irrigation (Im. After Dis. W.)[c]	106.5	245.5	1.20	0.84
			Irrigation (3d. After Dis. W.)[d]	106.4	237.9	1.19	0.82
			Irrigation (6d. After Dis. W.)[e]	103.7	223.7	1.19	0.81
			Irrigation (9d. After Dis. W.)[f]	108.8	226.1	1.18	0.79

[a]Intermittent flooding (1-day interval)

[b]Intermittent flooding (2-day interval)

[c]Irrigation (immediately after disappearance of water from the soil surface)

[d]Irrigation (3 days after disappearance of water from the soil surface)

[e]Irrigation (6 days after disappearance of water from the soil surface)

[f]Irrigation (9 days after disappearance of water from the soil surface)

Hasani cultivars, respectively. For Kooshkak site, the lowest and highest evaporation were gained in intermittent flooding irrigation at 2-day intervals and sprinkler irrigation (1.5*ET$_P$), respectively. In addition, the lowest and highest WP_T and WP_{ET} were obtained in sprinkler irrigation (1*ET$_P$) and intermittent flooding irrigation at 2-day intervals, respectively. The lower WP_T and WP_{ET} in sprinkler irrigation treatments are related to lower grain yield of rice as compared with continuous flooding irrigation treatment. Reduction in grain yield of rice by sprinkler irrigation as compared with continuous flooding irrigation

has been reported previously (Westcott and Vines 1986; McCauley 1990; Surek et al. 1996). For Rasht site, the lowest and highest evaporation were obtained in irrigation at 9 days after disappearance of water from soil surface and continuous flooding irrigation treatments, respectively, on average. For all cases, the highest ET was gained in continuous flooding treatments. The *Binam* cultivar produced a higher water productivity compared to the *Hasani* cultivar. It also seems that the *Champa-Kamfiroozi* cultivar had a high potential in a dry condition due to WP_T of 1.37 kg m^{-3} in intermittent flooding irrigation at 2-day

intervals. Based on the average, the amounts of WP_T and WP_{ET} were very close together in different irrigation treatments in Rasht.

Discussion

The results showed successful simulation of paddy rice growth in both very humid and semiarid climates using AquaCrop model. Therefore, AquaCrop can be used safely to simulate rice growth and irrigation management in these two regions. In addition, the model can be used to apply various water stress management scenarios, especially in a semi-arid region such as Kooshkak, and obtain an optimal scenario. According to the averages, canopy cover and biomass of rice were simulated with a good grade $(10\% < RRMSE < 20\%)$, while the simulation of the grain yield was excellent $(RRMSE < 10\%)$ by the model. The easiness of the AquaCrop model, the limited number of input parameters, and estimates accuracy introduce it as an appropriate model for simulating crop growth in different irrigation managements. Therefore, this model can be used as a decision support tool in increasing water productivity by a wide range of users, such as farmers, irrigation engineers and project managers. In the other words, the effects of different irrigation managements on water productivity can be simulated by AquaCrop and selected the optimal strategies to increase water productivity. The averages of WP_T and WP_{ET} for continuous flooding in the humid (1.21 and 0.82 kg m^{-3}, respectively) and dry (1.26 and 0.76 kg m^{-3}, respectively) climates showed the role of evaporation losses in decreasing WP in dry climate. The amount of evaporation in continuous flooding treatments for dry climate was 88% higher than humid climate. In addition, the results showed that the *Champa-Kamfiroozi* cultivar under intermittent flooding irrigation at 2-day intervals and the *Binam* cultivar under irrigation at 9 days after disappearance of water from soil surface can be considered as rice cultivation in the dry (Kooshkak) and humid (Rasht) climates, respectively.

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