ESTIMATION OF WATER PRODUCTIVITY AND CALIBRATION AND VALIDATION OF THE CROPSYST MODEL FOR RICE UNDER NITROGEN AND IRRIGATION MANAGEMENT

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Abstract. Simulation of yield response to water and fertilizer plays a key role in improving the efficiency of agricultural water. In this regard, the purpose of this study is the calibrating and validating of the CropSyst model to evaluate the effect of nitrogen fertilization and irrigation on the growth of rice in the crop field at the Rasht Rice Research Institute between 2013 and 2014. Three irrigation treatments (continuous, around five and eight days) were considered as the main factors and the amount of nitrogen in four concentration (0, 90, 120, and 150 kg N ha^{-1}) as a sub-factor. Based on the evaluation results it can be concluded that the CropSyst model, with the normalized root mean squared error ($RMSE_n$) 7 and 15% with explanation factor, R^2 of 0.73–0.84 for simulating the rice grain yield, and also $RMSE_n$ 9 and 10%, R^2 of 0.77–0.82 for simulating the biological yield, had the appropriate accuracy of the simulations. According to $RMSE_n$ 1 and 0.8%, R^2 of 0.58–0.73 for simulating the leaf area index, suggested a moderate simulation. These results showed that a reasonable estimate of the model as the efficiency of a model for the grain yield, biological yield, and LAI were 0.87, 0.98, and 0.80, respectively. The results of the simulation based on the amount of transpiration water productivity for both years showed that treatment I_3N_2 and I_3N_3had the highest amount. The amount of evaporation in irrigation water management two-year period only 39% of evapotranspiration is evaporated, While the amount of intermittent irrigation management 5 and 8 days, respectively, 35% and 32% respectively. These subjects simulations suggest that, given the good models and maximum data consistency, if management is aimed at maximizing the efficiency of water use can solve these models as a means to support the planning application.

Keywords: *intermittent irrigation, nitrogen, modeling, simulation*

Introduction

Water consumption improvement in agriculture is very important, compared with other sectors, because of the existing complexity in production, and the exploitation process and optimized application of irrigation water and nitrogen, especially in dry and semi-dry areas facing water constraints, is an important goal in this field (Raza et al., 2014). Climate changes, degrading of water resources and continuous drought has influenced agriculture in general and farmers' incomes specifically (Rezaei et al., 2013). As rice receives more irrigation water than other grain crops, developing water-saving

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irrigation approaches for rice re seen as a key component to deal with water shortages (Li and Barker, 2004). In recent years, many efforts have been applied in Iranian rice farms to decrease water consumption, and numerous reports have been published about the effect of low irrigation in decreasing water consumption and increasing rice efficiency (Pirmoradian et al., 2004; Razavipour and Kavosi, 2007). According to these reports, by changing the irrigation method from flood to intermittent irrigation without decreasing yield, or with an acceptable percent in decline, we can economize the use of water and increase the efficiency (Asadi et al., 2003). One of the most important zones of rice production in Iran is Guilan Province. Currently, climate change, reduction of fresh water, inappropriate use of water resources, construction of several dams across the White River basin, and the drought in the agricultural sector have threatened rice production and the income of farmers in the region (Zare et al., 2014)

These reports showed that permanent flood irrigation is not only a necessity but, also in dry and semi-dry areas in which the higher efficiency is important, we need to accept the expense of management to decrease the time and amount of irrigation (Razavipour and Kavosi, 2007). Additionally, in some cases, the average water pressure was recommended for better yield (Asadi et al., 2003). In some physiological periods of rice, intermittent pressure, as compared with permanent flood irrigation, caused an increase in the yield, although increasing the pressure will result in a decreased yield (Asadi et al., 2003).

Due to different intervals of time and place, it is difficult to determine various levels of yield through farm experiments. As such, computer simulation models can be used as appropriate tools for cultivation system studies and prepare optimized consumption patterns for the two inputs. Using simulation models is a way to predict and check water balance, growth process simulation, and the study of different management scenarios (Amiri and Rezaei, 2013a). One of the effective methods to reach these goals is the use of some models for plant growth, such as CropSyst (Crop Simulation System), which is a simulation model for rice growth that enables us to obtain the correct results through calculations of data statistics regarding the situation of water, weather, Earth, management system, and plant genetics *(*Amiri and Rezaei, 2013b). By using this model and its results, we can prevent excess consumption of water and nitrogen fertilizers.

Improvement of the CropSyst model was started by Stokel and colleagues in 1994. CropSyst had been developed during the last 15 years to a multi-crop, multi-year simulation model and can be connected to GIS software, which consist of programs like the CropSyst cultivation simulator system, reconstruction of meteorological data (ClimGen), GIS connection program (ArcCs), watershed models, and several other useful programs (Singh, 2008). This model has been used in various cases and in different areas (Saadati et al., 2012). In Southeast Australia, the CropSyst model could simulate the phenology, dry material, and the yield of wheat, green pea, and mustard (Diaz-Ambrona et al., 2001). Quite well. Since the 1980s, crop modellers have been pointing their attention on rice productions. Part of the APSIM crop models (Confalonieri et al., 2009), and the models of the CERES family basically implement a RUE based approach. Part of the models include crop growth equations based on the transpiration use efficiency (Keating et al., 2003). WARM (Confalonieri et al., 2006) is a novel model for paddy rice simulations developed by an interdisciplinary network of scientists working in different fields of rice research and modelling. The simplified model (CropSyst) may cost less in parameterization terms than the more complex models to achieve a similar level of confidence in the results, but WARM proved more accurate than the simplified model. The complexity of WOFOST is required to test hypotheses about processes at a lower level (Confalonieri et al., 2006). Therefore, models that are relatively simple to use with minimal input data that is readily available or easy to obtain may be a more useful analytical tool for technical staff, water managers, policy makers and other end-users in less developed countries (Khov et al., 2017).

Regarding the importance of rice cultivation in Guilan Province, and the necessity to optimize economic use of agriculture inputs, and the need to use simulation models of plant growth in irrigation management, this experiment has been conducted with the aim of gaining the best management for irrigation, nitrogen, and evaluate the application of the CropSyst model for rice yield under various water and nitrogen management scenarios.

Materials and methods

Field experiments

A two-year field experiment was conducted at the experimental farm of the Iranian Rice Research Institute in Rasht (37’ 12° N; 49’ 38° S; 7 m below sea level) from 2013–2014. The experimental design was a split plot with a complete randomized block and three replicates. The plot size for the subplots was 15 m^2 (3 m × 5 m). In this experiment, the main plots were three irrigation regimes: pond during growth period as a control treatment (I1), 5-day intervals (I2), and 8-day intervals (I3), and subplot treatments of four levels of N (no N application (N1), 90 kg (N2), 120 kg (N3), and 150 kg (N4)); urea was the source of N. A mixed commercial fertilizer was applied at the rate of 25 kg ha^{-1} of phosphorus (P) (in the form of phosphorus pentoxide (P_2O_5)) and 75 kg ha^{-1} of potassium (K) (in the form of dipotassium oxide (K_2O)). The rice variety ‘spring’ resulted in the highest yield in Guilan Province. Field experiments (*Table 1*) were carried out on a clay soil tissue (9% sand, 44% silt, and 47% clay). For determining the soil characteristics site of this experiment, several random samples of soil were obtained from a depth of 0–30 cm before transplanting and adding fertilizers and, after mixing soil samples, soil was sent to the laboratory for analyzing the soil in terms of physical and chemical properties (the results are shown in *Table 1*). Nitrogen fertilizer was applied three times during bolting, 50% at the time of transplanting to the field, 25% at maximum tillering, and 25% of the land. Irrigation was applied 20 days after transplanting management and to measure how many water counters in each plot were used.

Daily weather data on maximum and minimum temperatures, rainfall, and sunshine hours were collected for the entire growing season from a meteorological station beside the Iranian Rice Research Institute (*Fig. 1*).

Table 1. *Characteristics of the used soil*

pH of dough	**Total N (%)**	**OC (%)**	**P (ppm)**	**K (ppm)**	**CEC (meq/100 g)**	**Tissue**	**Depth soil (cm)**
7.2	0.13	1.32	11.9	188	31	Clay	30-0

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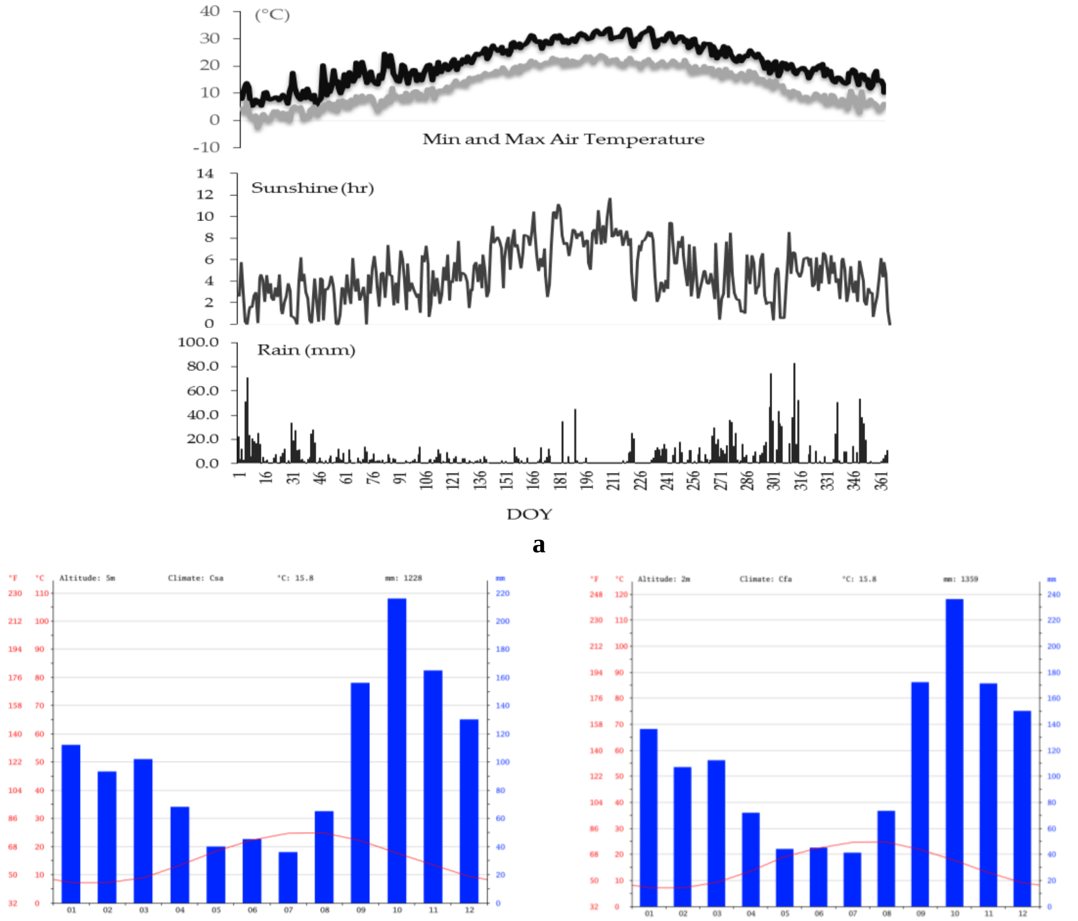

a

b

c

Figure 1. *a: Measured daily meteorological variables at the study site for the two years of the experiment (from 1 January 2013–22 September 2014). DOY is day of year. b, c: Measured daily Temperature and rainfall at the study site for the two years of the experiment (2013, 2014)*

The continuous irrigation amount during the growing season was about 5 cm. Samples of each plot have been studied with respect to the growth using a destructive analysis method. Plant harvesting was on 11–15 August in all years of the experiment. All plots were bonded and separated by 0.5-m-wide strips of bare soil to avoid lateral movement of water and nutrients among treatments. The plots were hydrologically separated by plastic sheets installed 40 cm below the soil surface to restrict water and N flow between adjacent plots. Measurements of samples were collected at the beginning of transplanting in all treatments, Crop samples were taken at regular intervals of 10–15 days to determine leaf area index (LAI) and total and panicle biomass over two years. The LAI of plants was measured by a Model GA-5 manufactured by OSK Japan meter. In other to evaluation of biological yield, 1 m^2 of each plot were harvested (Includes all vegetative and reproductive organs of plants top of the soil) and then placing it in the oven until (Drying machine plant material) dried.

CropSyst model descriptions

Version 3 of the CropSyst model was used in this study. Crop development was simulated on the basis of the accumulated thermal time required to reach each

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phenological stage. In order to evaluate the simulation effects of nitrogen fertilizer and irrigation on the growth yield of rice, some models were used which simulate the plant growth on a day-by-day and phase-by-phase basis to obtain the results. To run the models four sets of data were required as input. File locations, soil, and plant management definition, application, and all required parameters of the model range were stated in the manual model (Stöckle, 2003). Model inputs for the simulation consisted of daily weather information (including maximum and minimum temperature, precipitation, and solar radiation), soil (including physical and chemical properties of each layer), the cultivar characteristics (such as growth factors, growth, yield, and biomass) and crop management practices (including the use of irrigation and fertilizer), and the culture system (Amiri and Rezaei, 2013b).

Simulation model

Yield simulation of the CropSyst model depended on the total biomass, which accumulated at physiological maturity (B_{PM}), and the harvest index (HI = harvestable yield/aboveground biomass; *Eq. 1*):

$$Y = B_{\mathrm{PM}}\,\mathrm{HI} \tag{Eq.1}$$

Where Y is yield (kg m^{-2}) and B_{PM} is also in kg m^{-2}.

To introduce the processes of the CropSyst simulation, some equations are more important in this study, so they are presented here. Crop transpiration is dependent on biomass production (B_{Pt}) and LAI were effective in the output of CropSyst based on calibration results. The third equation is the yield, which was one of the main evaluated outputs. Therefore, these three equations are presented in this paper; also, more information can be found in another study (Stöckle et al., 2003). There is a relationship between crop transpiration and biomass production, which is based on carbon and vapor exchange in leaves. Thus, the potential daily biomass production can be calculated as (*Eq. 2;* Kumar et al., 2006):

$$AGB_{PT} = \frac{k_{BT} T_P}{VPD} \tag{Eq.2}$$

Where AGB_{PT} is the crop transpiration-dependent biomass production (kg m^{-2} day^{-1}), T_P is the crop potential transpiration (kg m^{-2} day^{-1}), VPD is Average daily steam pressure loss (kPa), and K_{BT} is a biomass-transpiration ratio (kPa).

Water productivity estimation

In this study, the amount of water productivity was calculated (*Eq. 3*) based on the sum of water and rainfall, with respect to the amount of water productivity $WP_{\mathrm{I+R}}$ (kg/m^2), where Y is the yield (kg/h), I is the amount of irrigation (mm), and R is the precipitation (mm). The amount of rainfall, evaporation, average maximum daily temperature, and irrigation in the years studied is shown in *Table 2*.

$$WP = \frac{Y}{I + R} \tag{Eq.3}$$

Table 2. *Amounts of water irrigation, precipitation, and evaporation and maximum temperature*

2014		**2013**		**Treatments**	
P	**I**	**P**	**I**	**Nitrogen**	**Irrigation**
59	804	79	744	N_1	I_1
	801		724	N_2	
	789		712	N_3	
	759		732	N_4	
	726		701	N_1	I_2
	741		703	N_2	
	746		701	N_3	
	746		707	N_4	
	419		469	N_1	I_3
	459		459	N_2	
	496		461	N_3	
	466		429	N_4	

Calibration of the models

Initially, soil, weather, and irrigation files were prepared similarly for all models. Then measured and estimated crop parameters were inserted in the models. After calibration of the model and determination of the optimal coefficients, a validation model was performed by using the second year of treatment (*Table 3*). In these models, plant development was measured with respect to temperature time (°C–days). From the start to the increase in the planting stage, temperature time must be specified for each phenological stage. Based on the type of plant phenology, the important and fundamental steps included the emergence, flowering, time of maximum leaf area index, end of flowering, start of grain filling, and physiological maturity.

Table 3. *Some relevant crop parameters used in the CropSyst model for the rice simulation*

Parameters	**Amount**	**Unit**
Optimum temperature (T_{opt})	27	°C
Maximum water uptake	10	mm day^{-1}
Maximum rooting depth	1.5	m
Maximum expected leaf area index (LAI)	5.9	$m^2 m^{-2}$
Specific leaf area (SLA)	30	$m^2 kg^{-1}$
Leaf duration	750	°C-days
Extinction coefficient for solar radiation (k)	0.5	-
Emergence Stage	135	°C-days
Peak LAI	1350	°C-days
Begin flowering	1290	°C-days
Begin grain filling	1300	°C-days
Physiological maturity	1900	°C-days
Base temperature (T_{base})	12	°C

Model evaluation

Several statistical methods were used to compare the simulated and observed results. In this article, we used a combination of graphical analyses and statistical measures to compare the simulated and measured final biomass and yield and LAI graphically. In this article, we evaluated model performance by using the absolute root mean square error (RMSE), normalized root mean square error ($RMSE_n$), coefficient of residual mass (CRM), coefficient of determination (R^2), and effective modeling (EF). RMSE, $RMSE_n$, CRM, and R^2, index of agreement (IOA), and EF characteristics are common tools to test the goodness of fit of simulation models (*Eqs. 4–9;* Pala et al., 1996; Fila et al., 2003):

$$RMSE = \left[\frac{\sum_{i-1}^{n} \left(P_i - O_i\right)^2}{n} \right]^{1/2} \tag{Eq.4}$$

$$RMSEn = \frac{RMSE}{\overline{O}} \tag{Eq.5}$$

$$R2 = \frac{\sum_{i-1}^{n} \left(P_i - O_i\right)^2}{\sum_{i-1}^{n} \left(O_i - \overline{O}\right)^2} \tag{Eq.6}$$

$$EF = \frac{\sum_{i-1}^{n} \left(O_i - \overline{O}\right)^2 - \sum_{i-1}^{n} \left(O_i - \overline{O}\right)^2}{\sum_{i-1}^{n} \left(O_i - \overline{O}\right)^2} \tag{Eq.7}$$

$$CRM = \frac{\sum_{i-1}^{n} O_i - \sum_{i-1}^{n} P_i}{\sum_{i-1}^{n} O_i} \tag{Eq.8}$$

$$IOA = \frac{\sum_{i-1}^{n} \left(P_i - O_i\right)^2}{\left|\left(P_i - \overline{P}\right)\right| + \left|\left(O_i - \overline{O}\right)\right|} \tag{Eq.9}$$

Where Pi is the simulated value, Oi is the measured value, and n is the number of measurements. The simulation was considered excellent if the normalized RMSE was less than 10%, was considered good if the normalized RMSE was greater than 10% and less than 20%, was considered fair if the normalized RMSE was greater than 20% and less than 30%, and was considered poor if the normalized RMSE was greater than 30%. The amounts of RMSE and $RMSE_n$ were at an optimum status if the simulated and observed were the same, and was equal to zero. If the *p*-value (*p*(t)) from the paired *t*-test was greater than 0.05, it was concluded that there were no significant differences existing between the measured and simulated values (Eitzinger et al., 2004). The IOA is also used to evaluate the model; it is a descriptive parameter value between zero and one, indicating how weak the model is in predicting results (Eitzinger et al., 2004).

Results and discussion

Calibration of the models

Initially, soil, weather, and irrigation files were prepared similarly for all models. Then, measured and estimated crop parameters were inserted in the models. The crop parameters used in this study are presented in *Tables 4–6* for the models. A revalidation of the model depends upon its successful calibration based on field experimental data, and the accurate estimation of the specific model's coefficients in a given environment (Eitzinger et al., 2004).

Validation and evaluation of the models

The model validations were based on the comparison between simulated and observed data for all treatments other than those used in the model calibration. Results showed that the average grain yield of RMSE under calibration and validation conditions was 461 and 847 kg per hectare, respectively. The average $RMSE_n$ of grain yield under calibration and validation conditions were 7% and 15%, respectively. The amounts of the measured grain yield showed a desirable simulation of this parameter in the agriculture season by the model which we could then use in irrigation planning and nitrogen rice fertilizer management (*Tables 4* and *6*). Araya et al. (2010) who report a deviation range of validation data of −13 to 15.1% for grain yield.

Table 4. *Observed and simulated grain yields and relative error for rice in 2013*

Treatment		Relative error (%)	Simulation grain yield (kg/ha)	Observed grain yield (kg/ha)
Irrigation	**Nitrogen**			
I_1	N_1	15	5053.8	4382.5
	N_2	7	6533.6	6120.1
	N_3	–15	6525.6	7664
	N_4	–2	6953.6	7093
I_2	N_1	3	5273.3	5135
	N_2	–1	6001	6084.4
	N_3	3	6825.9	6648.2
	N_4	10	7163.1	6478
I_3	N_1	9	5024	4596.3
	N_2	2	6405	6302
	N_3	13	7466	6604
	N_4	1	7213	7124

Table 5. *Calibration results of crop parameters in CropSyst model for rice simulation in 2013*

Plant parameters	EF	C_{RM}	IOA	T test	$RMSE_n$ (%)	RMSE	R^2	Number of samples
Biology Yield	0.98	0.06	0.97	0.13	9	1264	0.77	12
Grain Yield	0.89	–0.02	0.99	0.32	7	461	0.73	12
LAI	0.22	0.2	1	0.04	29	1	0.58	12

Notes: $RMSE_n$ (%) is the normalized root mean square error; R^2 is the adjusted linear correlation coefficient between simulated and measured values; EF is the efficiency of model; IOA is the index of agreement; T test: tested the amounts with respect to the mean; CRM is the coefficient of residual mass

Table 6. *Validation results of crop parameters in the CropSyst model for rice simulation in 2014*

Plant parameters	EF	C_{RM}	IOA	T test	$RMSE_n$ (%)	RMSE	R^2	Number of samples
Biological Yield	0.80	–0.04	0.96	0.27	10	1219	0.82	12
Grain Yield	0.98	–0.14	0.98	0.03	15	847	0.84	12
LAI	0.38	–0. 7	1	0.02	68	82	0.82	12

Notes: $RMSE_n$ (%) is the normalized root mean square error; R^2 is the adjusted linear correlation coefficient between simulated and measured values; EF is the efficiency of model; IOA is the index of agreement; T test: tested the amounts with respect to the mean; CRM is the coefficient of residual mass

The results of treatment evaluations showed that the average RMSE was equal to 847 kg per hectare, relative RMSE was 15%, and CRM was –0.14, which, compared with 386 kg per hectare, 8%, and 0.12, was greater than the calibration phase, and indicates the closeness of the simulation amounts and validation values. For both calibration and validation phases, the amount of CRM that excluded the maximum LAI and dry material in the first year was negative, which showed that the amount in the simulation in most treatments was more than the observation amounts. In other words, in most treatments, the estimated amount of the model was more than the real amounts. Ouda et al. (2015), who reported The RMSE was 8% of the mean observed yield.

The EF under the calibration and evaluation conditions was also 0.89 and 0.87, respectively. Based on the studies, simulation of this model under different levels of nitrogen was performed on corn plants, and the EF of the calibration and evaluation phases were 0.52 and 0.90, respectively (Mohseni, 2008). Additionally, in other studies of the simulation of wheat plant yield by the CropSyst model, the value of the RMSE was equal to 0.21 Mg/ha and the value of the correlation factor was 0.72 (Sadras, 2002). Modeling efficiency (EF) were 0.82 and 0.75 for biomass and soil water content, respectively (Bellocchi et al., 2002; *Tables 5* and *6*)

According to the research on the simulation of rice plant yield in North Italy, using the CropSyst model, the $RMSE_n$ amplitude of dry material simulated measured for the calibration and validation year was 11%–29% and 10%–52%, respectively, and the CRM amplitude of dry material simulated measured for calibration and validation years was –0.03% to 0.17% and –0.02% to 0.17%, respectively (Confalonieri and Bocchi, 2005). Moreover, based on studies of the evaluation of the CropSyst model on the simulation of both the effects of water and nitrogen on wheat plants, the value of the RMSE for the simulation yield in the CropSyst model was 0.36 Mg/ha. The value of the RMSE for the simulation of dry material in CropSyst was 1.27 Mg/ha (Saadati et al., 2012). The comparison of these results with the values gained in this research for rice plants showed that the CropSyst model could also simulate the rice yield well.

Results showed that the average RMSE yield biology under calibration and validation conditions were 1264 and 1219 kg per hectare respectively. The amounts of average $RMSE_n$ yield biology under calibration and validation conditions were also 9% and 10%, respectively. The EF that was obtained under calibration and evaluation conditions is also equal to 0.99 and 0.80, respectively. For performance recognition of the CropSyst model in the simulation of dry material production and the yield of the reaction to the water and nitrogen, researchers studied the separate products in a season under experimental conditions with extensive preparations from dry to full irrigations and from low nitrogen existing in the soil to high level conditions. In these evaluations, the reported value of RMSE was 0.443 t/ha (Pala et al., 1996). Simulation results showed satisfactory application by suitable value of RMSE of biomass growth (0.58-3.52 t ha^{-1}) and water content in the soil profile (20.9-50.6 mm) (Raza et al., 2014).

Results showed that the average RMSE under calibration and validation conditions were 1 and 0.80 m^2 of leaf surface in each square meter at ground level. The values of $RMSE_n$ for the maximum LAI under calibration and validation conditions were 29 and 23, respectively. The results showed an acceptable accuracy of this model for simulation of the maximum LAI. The amounts of the measured parameters indicated that the medium simulation of this parameter, as well as the agriculture season by which this model can be used for planning of rice irrigation and nitrogen fertilizer management. The EF under calibration and evaluation conditions obtained were 0.12 and 0.32, respectively.

Our observations showed that relative error of simulation yield in the calibration phase was –15% to 15% and, in the evaluation phase, it was between 2% and 52%. Additionally, the amount of biomass simulation relative error in the calibration phase was –22% to 2% and in the evaluation phase, it was between –10% and 27%. Other research indicated that the amplitude amount of error for the growth simulation of the wheat plants between the simulation and observation yield in this plant was 2.7–37.2% and, for dry material, it was between 2.2–30% (Mohseni et al., 2008). Results showed that R^2 for the calibration model data was 0.84, which means that the model is suitable for grain yield simulation. Additionally, a relatively high R^2 value means low dispersion of the data (Amiri and Rezaei, 2013a).

The amount of IOA (Willmott agreement index) was one of the most important indicators of the plants' assessment modeling. The IOA under calibration (first year) conditions for maximum LAI, grain yield, and dry material was 1, 0.99, and 0.97, respectively. Additionally, the IOA under evaluation conditions for maximum LAI, grain yield, and dry material was 1, 0.98, and 0.96, respectively. Results of the research by Zhang et al. (2011) show that IoA was in the excellent range (Zhang et al., 2011).

Tables 7–11 show the comparisons between the amounts of simulated and measured grain yield.

Table 7. *Observed and simulated grain yields and relative error for rice in 2014*

Treatment		**Relative error (%)**	**Simulation grain yield (kg/ha)**	**Observed grain yield (kg/ha)**
Irrigation	**Nitrogen**			
I_1	N_1	34	4867	3646.5
	N_2	12	6622.6	5907.1
	N_3	5	6614.6	6307
	N_4	2	6705	6577
I_2	N_1	52	5276.3	3476.3
	N_2	19	7225.1	6097
	N_3	28	7266	5677
	N_4	11	6966.8	6302
I_3	N_1	29	5030.1	3907.3
	N_2	8	6470	5684.9
	N_3	7	7040.4	6610
	N_4	6	7140	6712

Table 8. *Observed and simulated LAI and relative error for rice in 2013*

Treatment		**Relative error (%)**	**Simulation LAI**	**Observed LAI**
Irrigation	**Nitrogen**			
I_1	N_1	89	3.19	2.28
	N_2	9	4.31	4.13
	N_3	5	4.25	4.6
	N_4	12	4.87	4.82
I_2	N_1	39	3.55	1.73
	N_2	33	4.69	2.83
	N_3	20	4.69	2.62
	N_4	36	4.19	4.9
I_3	N_1	4	2.4	1.68
	N_2	26	4.52	3.59
	N_3	31	5.3	3.8
	N_4	16	4.8	5

Table 9. *Observed and simulated LAI and relative error for rice in 2014*

Treatment		**Relative error (%)**	**Simulation LAI**	**Observed LAI**
Irrigation	**Nitrogen**			
I_1	N_1	45	3.3	2.28
	N_2	-3	4.01	4.13
	N_3	-4	4.42	4.6
	N_4	2	4.9	4.82
I_2	N_1	106	3.65	1.73
	N_2	74	4.89	2.83
	N_3	79	4.89	2.62
	N_4	0	4.89	4.9
I_3	N_1	19	3.34	1.68
	N_2	24	4.4	3.59
	N_3	17	4.49	3.8
	N_4	-8	5.32	5

Table 10. *Observed and simulated biomass and relative error for rice in 2013*

Treatment		**Relative error (%)**	**Simulation biomass (kg/ha)**	**Observed biomass (kg/ha)**
Irrigation	**Nitrogen**			
I_1	N_1	–2	10,107	10,335
	N_2	–2	13,066	13,366
	N_3	–15	13,051	15,397
	N_4	–22	13,720	17,571
I_2	N_1	2	10,549	10,371
	N_2	–1	14,326	14,532
	N_3	1	14,081	13,962
	N_4	–7	14,100	15,100

I_3	N_1	–3	10,049	10,386
	N_2	–7	12,811	13,772
	N_3	–9	14,221	15,684
	N_4	–6	14,062	14,985

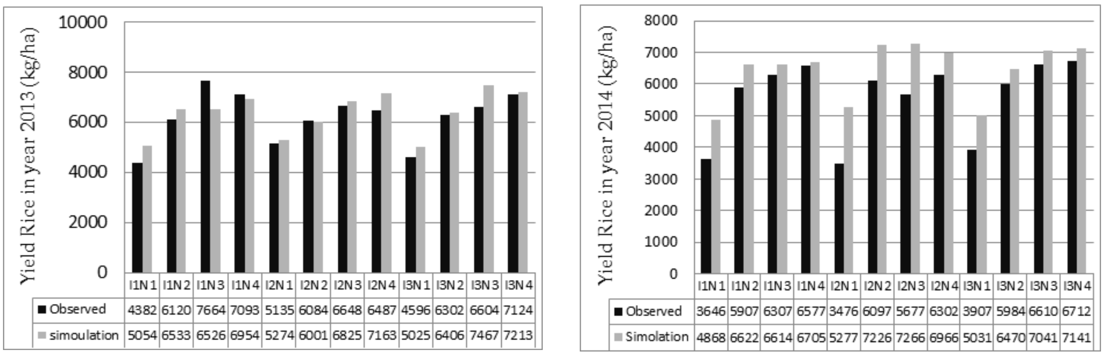
Table 11. *Observed and simulated biomass and relative error for rice in 2014*

Treatment		**Relative error (%)**	**Simulation biomass (kg/ha)**	**Observed biomass (kg/ha)**
Irrigation	**Nitrogen**			
I_1	N_1	17	9735	10,335
	N_2	18	13,244	13,366
	N_3	–5	13,228	15,397
	N_4	0	13,688	17,571
I_2	N_1	15	10,553	10,371
	N_2	7	14,451	14,532
	N_3	–3	14,532	13,962
	N_4	–4	14,232	15,100
I_3	N_1	26	9661	10,386
	N_2	27	12,940	13,772
	N_3	–4	13,241	15,684
	N_4	–10	13,451	14,985

Results showed a change from flood to intermittent irrigation, the real grain yield decreased, and the increase of nitrogen consumption led to the grain yield increasing. The model also showed a decrease and an increase in simulated grain yield pretty well. The minimum amount of grain yield was under the condition of the non-use of nitrogen fertilizer, and the maximum yield was under the nitrogen treatment condition of 120 kg N per hectare, with intermittent irrigation was every 5–8 days.

It is worth noting that low irrigation is also effective in this matter. In 5-day irrigation management, the model could not simulate the yield well because of incompetent ability to estimate grain yield. The existence of some weather parameters, such as wind speed and carbon dioxide changes in the farm, which were not present in the model (the model anticipates grain yield according to other climate parameters) might also be another reason for the decrease in foresight accuracy by the model (Honar et al., 2010).

In testate fertilizer amounts, the error percent of the model was higher, but it will be decreased by increasing the fertilizer amounts so that after forth fertilizer application the error will be erased completely. Changes in the amount of simulated grain yield by the CropSyst model for the first and second year are shown in *Figure 2*. The minimum amount of grain yield was under the condition of the non-use of nitrogen fertilizer, and maximum yield was under nitrogen treatment condition of 120 kg nitrogen per hectare and intermittent irrigation was every eight days. The results showed that the gain yield would increase by increasing the nitrogen consumption. The model also showed fluctuations in simulated grain yield rather well. The amount of grain yield will increase by adding more nitrogen via irrigation management, but in higher levels of nitrogen (150 and 120 kg ha^{-1}) a slight increase will be shown. According to other indices to assess irrigation regimes and fertilizer levels, the most suitable treatments regarding environmental aspect were 5-day irrigation regime and 45 kg N ha^{-1} (Zare et al., 2014).



a **b**

Figure 2. *Observed and simulated grain yields for rice in 2013 and 2014. Irrigation. (I1 = continuously flooded, I2 = 5 per day, I3 = 8 per day) and N fertilizer (N1 = 0, N2 = 90, N3 = 120, N4 = 150 (kg/ha))*

On the other hand, the grain yield will decline under flood irrigation conditions. Additionally, by changing the irrigation model from flood to intermittent treatments of every 5–8 days, simulated grain yield will show a slight increase; this indicates that the amount of nitrogen consumption is more than the nutritional needs of the spring type of rice in this research. Changing of the irrigation from flood to intermittent will reduce hydrostatic pressure at the ground level, which causes a reduction of water loss through leakage and deep percolation (Bouman et al., 2007).

Results of the research showed that the change in flood irrigation management reduced deep losses. Therefore, investigation of results about the amount of leakage and deep percolation in the period of the research showed the minimum and maximum water loss through deep percolation as 117 and 221 mm, respectively, under flood and non-flood management (Amiri and Rezaei, 2013a). Results also indicated that changing from flood to non-flood irrigation reduced irrigation water, which was consistent in other studies (Pirmoradian et al., 2004; Amiri and Rezaei, 2013a).

Other studies showed that changing the irrigation method from flood to non-flood will result in saving irrigation water. Due to the increasing competition for water, water-saving technologies, such as alternate wetting, drying, and aerobic rice are being developed to reduce water consumption while maintaining a high yield. The components of the water balance of these systems need to be disentangled to extrapolate water savings from the field scale to the irrigation system scale (Bouman et al., 2007). As shown in this study, irrigation and N fertilizer management improved the efficiency of water consumption and, thus, reduced the impact of water shortages. The results of this study provided a basic information base for making irrigation and N management decisions in the study area.

Water productivity estimation

The amount of water productivity was calculated based on the sum of water and rainfall, as shown in *Table 12*. The results show that the change in flood irrigation management increased water productivity. The model also showed the simulated decrease and increase rather well. Additionally, results from the treatments of I_3N_3 and I_3N_4 in both models showed the greatest amount of water productivity was in the first and second years. This result suggests that the mechanism of the plant's production performance, despite the reduction in available water to the surface, has been successful. Furthermore, the value of the evaporation results in the CropSyst model showed that, in irrigation flood management, up to 39% of evapotranspiration occurs. While the value of intermittent irrigation management of five and eight days, respectively, was 35% and 32%. The amount of water productivity was calculated based on the sum of water and rainfall, with greater reliance on management practices, especially irrigation methods. The results Jalotal et al. (2006) suggest that water productivity in rice can be enhanced mainly by adjusting the transplanting date. The enhanced water productivity in delayed transplanted paddy was due to reduction in ET while the yield remained unaffected (Jalotal et al., 2006). Results of the research by Umair et al. (2017) E was 30% of total ETa and results closely matched the observed data collected during the MLM and isotopes approach (Umair et al., 2017).

***Table 12**. Simulated grain yield and water productivity amounts via the CropSyst model*

Year	Irrigation	Nitrogen	P (mm)	I (mm)	E (mm)	ET (mm)	GY (kg/h)	*WP*
2013	I_1	N_1	79	744	330	537	5053/8	0.61
		N_2	79	724	350	586	6533/6	0.81
		N_3	79	712	347	550	6525/6	0.83
		N_4	79	732	363	544	6953/6	0.86
	I_2	N_1	79	701	340	487	5273/3	0.68
		N_2	79	703	329	495	6001	0.77
		N_3	79	701	382	498	6825/9	0.88
		N_4	79	707	385	464	7163/1	0.91
	I_3	N_1	79	469	270	429	5024/1	0.92
		N_2	79	459	273	444	6405	1.19
		N_3	79	461	297	431	7466/4	1.38
		N_4	79	429	331	431	7213	1.42
2014	I_1	N_1	59	804	330	533	4867/8	0.56
		N_2	59	801	407	586	6622/6	0.77
		N_3	59	789	347	550	6614/6	0.78
		N_4	59	795	360	544	6705/6	0.79
	I_2	N_1	59	726	319	550	5276/3	0.67
		N_2	59	741	362	551	7225/1	0.9
		N_3	59	746	382	493	7266/9	0.9
		N_4	59	746	360	502	6966/18	0.87
	I_3	N_1	59	419	271	518	5030/1	1.05
		N_2	59	459	318	436	6470	1.2
		N_3	59	496	251	439	7040/4	1.27
		N_4	59	466	330	429	7140	1.3

I1 = Continuously flooded, I2 = 5 per day, I3 = 8 per day and N fertilizer N1 = 0, N2 = 90, N3 = 120, N4 = 150 (Kg/ha)

P = Precipitation, *I* = Irrigation, *E* = Evaporation, *ET* = Evapotranspiration, *GY* = Grain Yield, *WP* = Water productivity

Results of the research by Amiri and Rezaei (2013a) show that the change in flood irrigation management reduces deep losses (Amiri and Rezaei, 2013a). So that investigation of results about the amount of leakage and deep percolation in a period of the research show the minimum and maximum of water dissipation through deep percolation as 117 and 221 mm, respectively, in flood and non-flood conditions. Results of that study also indicates that changing from flood to non-flood irrigation reduces irrigation water consumption, which is consistent with the research of Pirmoradian et al. (2004). They showed that changing irrigation methods from flood to non-flood will result in saving irrigation water (Pirmoradian et al., 2004).

Irrigation and N fertilizer management, as shown in this study, improves the efficiency of water use and, thus, reduces the impact of limited water. The results of the study provided an information base for making irrigation and N management decisions in the study area. These results suggest that due to the good simulation models and maximum data consistency that the CropSyst model can be used to support the management and optimization of water and nitrogen fertilizer to cultivate rice.

Conclusions

The CropSyst model was sufficiently accurate in the simulation of yield underwater-saving and crop density conditions for our study site. The results of this study clearly indicate that the CropSyst model can be used with a high degree of accuracy for yield simulation and were similar to those of other researchers (Asadi et al., 2003; Bouman et al., 2007; Amiri and Rezaei, 2013a; Umair et al., 2017). The CropSyst model could also simulate the rice yield rather well. An agreement index (IOA) was also used to evaluate the model. Given the negligible difference between observed and simulated value performance, it can be concluded that this model might be useful as a simulated model of the effect of water and nitrogen management which can be used in yield estimates. The results of this study showed that the model generally predicted grain yield and final biomass fairly satisfactorily across a range of datasets covering levels of irrigation and N conditions within two years in Northern Iran.

Thus, the most optimal conditions to offer to farmers was under nitrogen treatment condition of 120 kg nitrogen per hectare and intermittent irrigation was every eight days.

In the current study, the CropSyst crop simulation model was calibrated, validated, and used as a tool to provide estimates of water productivity of rice under a range of N fertilizer and water regimes in a humid region of Iran. The simplicity of the model in its required minimum input data, which are readily available or can be easily collected, makes it user friendly. The authors suggest that for better validation of models using other models and other concentration Nitrogen and Irrigation Management in Other areas suitable for rice cultivation.

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