USING AQUCROP MODEL FOR SUPPLEMENTARY AND RAIN FED IRRIGATION IN NORTH IRAQ

UTILISATION DU MODELE AQUACROP DANS L'IRRIGATION SUPPLEMENTAIRE ET PLUVIALE AU NORD DE L'IRAK

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ABSTRACT

Iraq has a semi arid climate. Here, water rather than the land is the key factor in the improvement of the agriculture production. Therefore, in order to have an optimal water and crop management, some modern techniques tools were used. Firstly, the observed soil moisture distribution, and daily evapotranspiration rate have been compared with those obtained from the application of HYDRUS1D model. Secondly, AquaCrop model was used to compare experimental field data of the biomass production of wheat in three regions within Nineveh governorate north of Iraq using both rain fed and supplementary irrigation with the corresponding model output. HYDRUS1D gives reasonable agreement with the observed data over the time of the wheat growth season and through the depth of the soil column. The percentage of this agreement was around 95%. On the other hand, AquaCrop model outcomes show poor agreement in terms of soil moisture especially with the deeper depths for both types of irrigation applications (i.e. rain fed and supplementary method). As aforementioned, AquaCrop model was evaluated according to biomass production of wheat crop data. The available data were concerning three different regions in Nineveh governorate in northern part of Iraq, viz, Hamam Alalel, Aljazerra project and Telkeef regions(map showing those reigons is essential) using rain fed and supplementary irrigation. The agreement between the predicted yield values by AquCrop model and those obtained from experiments varies from very good agreement to good, depending on the region, time and soil type. For instant, the results obtained from the application of the model for Hamam Alalel region in terms of wheat growth gave 95% agreement with the experimental data using the R2 as a measure of agreement for rain fed wheat. However, only 25% increase was achieved when switched has been made to supplementary

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irrigation which is not satisfactory. The same conclusions can be drawn for the other two regions.

Key words: *AquaCrop Model, supplementary irrigation, HYDRUS1D Model*

RESUME

L'Irak a un climat semi-aride. L'eau plutôt que la terre est le facteur clé dans l'amélioration de la production agricole. Par conséquent, pour la gestion optimale de l'eau et des cultures, les outils techniques modernes ont été utilisés. Tout d'abord, la distribution de l'humidité des sols observée, et le taux d'évapotranspiration quotidienne ont été comparés avec ceux obtenus par l'application du modèle HYDRUS1D. Ensuite, le modèle AquaCrop a été utilisé pour comparer les données d'expérimentation obtenues sur le terrain de la production de biomasse du blé dans trois régions au sein du gouvernorat Ninive au nord de l'Irak à l'aide de l'irrigation supplémentaire et pluviale avec le rendement obtenu du modèle. HYDRUS1D s'accord avec les données observées au cours de la période de la saison de croissance du blé et la profondeur de la colonne du sol. Le pourcentage de cet accord était d'environ 95%. D'autre part, les résultats du modèle AquaCrop montrent un accord faible avec l'humidité des sols en particulier dans le cas des profondeurs de deux types d'applications d'irrigation (pluviale et supplémentaire).

Le modèle AquaCrop a été évalué selon la production de biomasse des données agricoles du blé. Les données disponibles étaient relatives à trois régions différentes du gouvernorat Ninive au nord de l'Irak, à savoir, Hamam Alalel, projet d'Aljazerra et régions de Telkeef (carte montrant ces régions est essentielle) par l'irrigation pluviale et supplémentaire. L'accord entre les valeurs du rendement prédit par le modèle AquCrop et celles obtenues à partir d'expériences varie d'un très bon accord à la fois à la bonne dépendant de la région, du climat et du sol. Par exemple, les résultats obtenus de l'application du modèle dans la région Alalel Hamam en ce qui concerne la croissance du blé a donné l'accord de 95% par rapport aux données expérimentales utilisant le R^2 comme une mesure d'accord pour le blé pluvial. Cependant, seulement une augmentation de 25% a été constatée quand la méthode d'irrigation supplémentaire a été utilisée qui n'était pas satisfaisante. Les mêmes conclusions peuvent être tirées pour les deux autres régions.

Mots clés: *Modèle AquaCrop, irrigation supplémentaire, modèle HYDRUS1D*

1. INTRODUCTION

Iraq faces challenge due to limited sources of water coupled with rapidly growing demand of water. Precipitation in the Nineveh governorate, Iraq is of Mediterranean type with low annual amount and uneven distribution over the growing season plus great year-to- year fluctuation. Rainfall in this areas is lower than the crop water requirements for economic production. Soil moisture in the root zone would not satisfy crop needs over the whole season. The soil moisture stored from rainfall in the wet months (December to March) is used by plants crops during the early growth stage. It does not support plant water need late at the most sensitive stage of crop growth. As a result of water stress, rain fed crops have poor growth and yield. North Iraq is one of the most important grain producing areas, especially for winter wheat where the wheat yield varies from 1 to 5 ton/ha, depending on the amount and the distribution of rainfall. These yield levels are far below the yield potential of wheat. The production of wheat in this area is not reliable due to uncertainties of rain.

Iraq has initiated ambitious plans to develop agriculture in this area. These plans comprise the enhancement of the developed technologies for efficient use of water resources. For example a large supplemental irrigation project (the North Aljazeera Irrigation project) was constructed to serve approximately 100,000 ha using a linear-move sprinkler Irrigation system. In addition to that, novel technologies were introduced in the framing system like drip irrigation. Particularly, in the rain fed areas, efforts have been made to increase wheat production with targeted goal to plant of up to 0.5 million hectares of wheat with supplemental irrigation.

In this context, deficit irrigation is an option that may increase WUE, but would most certainly improve resource sustainability. The loss in production will depend on the extent of deficit, which may be more than compensated when the real value of water is taken into account. In practice, optimal scheduling of deficit irrigation requires a good understanding of crop response to water stress. Crop simulation models can be of great help toward this end. Simulation models have been used for decades to analyze crop responses to environmental stresses and to test alternate management practices (Boote et al., 1996; Sinclair and Seligman, 1996). Crop yield response to water has been framed in a few simple equations in the past (Hanks, 1974), while more sophisticated and mechanistic simulation models were developed in recent decades (Uehara and Tsuji, 1998; Ahuja et al., 2002). However, the tradeoff between simplicity and accuracy of the models remains an issue of concern if their broad application is to be achieved. Recently, the FAO of the United Nations addressed this concern by developing the AquaCrop model. This simulation model evolved from the basic yield response to water algorithm in Doorenbos and Kassam (1979) to a daily-step, process-based crop growth model with limited complexity. AquaCrop is described in its conceptual framework and algorithmic solutions in Steduto et. al. (2009) and Raes et al. (2009).

In many dry areas of the world, like northern Iraq and areas of the Mediterranean, winter wheat is grown under rain fed and supplementary irrigation (Oweis and Hachim,2033).

The AquaCrop model is developed to strike a balance among simplicity, accuracy, and robustness. AquaCrop has a relatively limited number of input parameters for ease of use and greater appeal to agricultural extension, consultants, and practitioners. It has a water-driven growth-engine for field crops with a growth-module that relies on the conservative behavior of biomass per unit transpiration (Tr) relationship (Hsiao and Bradford, 1983; Steduto et al., 2007). AquaCrop is a menu driven program, with a set of input files that describe the soil–crop–atmosphere environment in which the crop develops, in addition to the seasonal field practices. The model is currently being tested for various crops across a wide range of climate, soil, water deficit, and management conditions. One of the current study objectives is to parameterize and test AquaCrop model for winter wheat under rain fed- and supplementary -irrigation in a semiarid environment in northern part of Iraq.

As increasingly more complicated computer models are being developed for simulating subsurface flow and transport processes, the accuracy of numerical simulations largely depends upon the accuracy with which various model parameters can be estimated. Flow and transport models for the unsaturated zone are often based on numerical solutions of the

Richards equation which requires knowledge of the unsaturated soil hydraulic functions, i.e., the soil water retention curve, $\theta(h)$, describing the relationship between the water content θ and the pressure head h, and the unsaturated hydraulic conductivity function, $K(h)$, defining the hydraulic conductivity K as a function of h. This physically based approach uses Richards' equation that is based on Darcy's law and continuity equation. These models are generally applicable. They can be used for a precise description of water regime in an unsaturated and saturated soil profile and may be applied in fundamental research as well as in water management. Examples are HYDRUS-1D simulation model is of concern, for which have concluded that there are good agreement between the simulated and measured soil moisture over time and along soil column depth, (Jacques et al.,2003 and Šimůnek et al.,2006).

2. MATERIALS AND METHODS

The wheat crop, both rain fed and with supplemental irrigation chosen to parameterize and test the FAO Aqua crop model. Working with data sets were reported in north Iraq, field experiments at Hamam Alalel, Telkeef, Aljazerra) (Mohammed, 2000 and Al Nori, 2003) with different objective and different irrigation treatments were used to test Aqua Crop .The first experiment (Hamam Alalel) was performed in the farm of the Department of Soil and Water Resource in Hama Alalel. The second experiment was performed at the Telkeef region and the third at Aljazerra irrigation project.

AquaCrop ver 3.3 and Hydrus1D ver 3.1 packages had been used for simulating wheat growth and water distribution simulation.

Site Description

The experimental site is characterized by a Mediterranean climate with a single rainy season from the fall to early spring, 350 mm with no rainfall during the summer. MOSUL weather station measured daily values of minimum and maximum air temperature and relative humidity, precipitation, solar radiation, and wind speed at 2 m height. Daily reference evapotranspiration (ETo) was computed using the Penman–Monteith approach (Allen et al., 1998). Soil of the three sites in this study are: silty clay loam for both Hamam Al alel and Aljazerra regions , and clay loam for the Telkeef. The water table is deep.

Parameterrizaion of Aquacrop

Parameterization is a higher-level adjustment of specific model parameters than calibration, although the two are used interchangeably in some literature. Calibration is adjusting certain model parameters to make the model match the measured values at the given location. As for Aquacrop, there were no predetermined parameters for winter wheat, and thus parameterization was the primary goal. The model was parameterized for winter wheat using data from the 2000-2007 growing season. This included yield data from rain fed and supplemental irrigation. From the supplemental irrigation treatment, a good correlation was found between observed and simulated values. Table 1 shows those parameters.

Table 1. Calibrated crop parameters and program settings for Waha winter wheat inputs used for calibration of Crop inputs.

Input Calibrated	value
Initial canopy cover	9.38%
Cover per seedling	5 cm^2/plant
Plant density	187.5 plant /m^2
Type of planting method	sowing
Emergency day	7 day
Time to maximum canopy cover, calendar days	60 day
Maximum canopy cover,	85%
Time to senescence,	145 day
Time to harvest, calendar days	180 day
Flowering time	102 day
Maximum rooting depth	100 cm
Time to maximum rooting depth, calendar days	80 day
Canopy decline day	30 day
Building up Harvesting Index	70 day
Flowering duration days	20 day
Base Temperature	10 C0
Upper Temperature	30 C0

3. RESULTS AND DISCUSSION

AquaCrop Model Simulation

There is a good agreement between AquaCrop model simulation data and that obtained from winter wheat growth from different years from 1998 to 2006 and different locations (three locations in the same mosul governorate, which nearly far 60 kilometers from each other) Hamam Alalele, Telkeef and Aljazeera (Table 2). This good agreement was in both grain yield and biomass of wheat variety (waha) which was parameterized according to Table 1. In Aljazeera location form all the years of planting the convergence between observed and simulated are vary smaller than the two other locations and type of irrigation, But R^2 value between observed and simulated grain yield under rain fed irrigation and supplementary irrigation are 0.736 and 0.893, respectively. The R^2 values were higher under supplementary irrigation. The same trent was found with bio mass production (R^2 between observed and simulated data under rain fed and supplementary irrigation are 0.74 and 0.85, respectively. This implies that we can predict wheat product (grain and biomass) by AquCrop simulation with error up to 15%.

Table 2. Observed grain and biomass yield of wheat of waha type and simulated by AquaCrop at different years and locations, using rain fed and supplementary irrigation in (Ton / Hectare).

Year	Location	Rain fed irrigation				Supplementary irrigation			
		Observed		Simulated		Observed		Simulated	
		Yield	Biomass	Yield	Biomass	Yield	Biomass	Yield	Biomass
2000-2001	Al jazerra	1.32	2.98	1.37	3.08	2.15	4.45	2.22	4.66
2001-2002	Al jazerra	2.04	2.26	2.12	4.42	3.80	7.10	3.94	7.36
2002-2003	Al jazerra	2.01	4.86	2.23	5.39	2.97	6.63	3.03	6.76
2003-2004	Al jazerra	1.90	4.09	1.94	4.26	3.40	6.11	3.50	6.36
2004-2005	Al jazerra	1.20	3.34	1.37	3.83	2.45	5.30	2.57	5.58
2005-2006	Al jazerra	2.35	5.98	2.72	6.92	5.02	11.05	6.30	13.10
1997-1998	Hamam Al alele	2.63	5.90	2.38	6.27	3.38	6.68	3.30	7.11
2002-2003	Telkeef	3.05	5.34	2.38	5.27	3.83	8.80	3.38	7.09

This is also seen from Table 3 that the error percentage of simulated values from the observed ones range from 2% to 25 %, for grain yield and bio mass product under rain fed and supplementary irrigation, respectively. However, the simulated bio mass at Aljazeera in 2001-2002 was 95% higher than the observed value and this is attributed to the rain distribution, which was different in the simulation process than the actual.

Table 3. Error deviation percentage from simulated to the observed field results of wheat grain and biomass yield (waha type) under rain fed and supplementary irrigation .

Year	Location	Error percentage			
		Rain fed		Supplementary irrigation	
		Yield	Biomass	Yield	Biomass
		Ton/Ha			
2000-2001	Al jazerra	-3.9	-3.7	-3.1	-4.7
2001-2002	Al jazerra	-3.7	-95.3	-3.6	-3.7
2002-2003	Al jazerra	-10.9	-10.9	-1.9	-2.1
2033-2004	Al jazerra	-2.3	-4.2	-2.9	-4.2
2004-2005	Al jazerra	-14.5	-14.6	-4.9	-5.3
2005-2006	Al jazerra	-15.7	-15.7	-25.4	-18.6
1997-1998	Hamam Al alele	9.4	-6.1	2.3	-6.5
2002-2003	Telkeef	21.9	1.4	11.7	19.5

From Table 4 also AquaCrop give a very good correlation between observed and simulated Water productivity of grain yield of wheat plant (R^2 = 0.6 under rainfed and 0.95 with supplementary irrigation). This implies that we can make use of AquaCrop software for evaluating and predict how much water to be applied efficiently and economically, without doing a real experiment at the field.

Table 4. Water productivity of grain yield of wheat of waha type observed and simulated by AquaCrop in Kg/m^3.

Year	Location	Water Productivity of			
		Rain fed		Suplemental irri.	
		Grain yield, kg/m^3			
		Obs	Sim	Obs	Sim
2000-2001	Al jazerra	0.45	0.47	0.62	0.64
2001-2002	Al jazerra	0.64	0.67	0.92	0.98
2002-2003	Al jazerra	0.57	0.64	0.76	0.77
2033-2004	Al jazerra	0.61	0.63	0.79	0.82
2004-2005	Al jazerra	0.42	0.49	0.75	0.79
2005-2006	Al jazerra	0.54	0.62	1.03	1.3
1997-1998	Hamam Al alalele	0.71	0.64	0.72	0.70
2002-2003	Telkeef	0.82	0.64	0.81	0.91

AquaCrop and HYDRUS1D Simulation of Water Distribution

Figure 1 shows that rain fed bare soil with shallow soil depth gave high difference between observed and simulated results of AquaCrop model which have sensitive behavior to the water applied by rain, while the HYDRUS1D simulated results have the same trend of observed results, but of small diversion and of less sensitive to water added . As going deeper in the soil AquaCrop model results became more smooth , and became as straight line at depths 50 and 70 cm, this means very poor ability to simulate soil moisture at depths more than 10 cm . But the HYDRUS1D simulated results give very small diversion from observed results as going deeper in the soil, which show high ability to simulate soil moisture at all soil depths. Figure 2 shows how AquaCrop and HYDRUS1D models simulate bar soil moisture with supplementary irrigation (water applied as 75% of soil moisture depleted). AquaCrop model highly react with water applied , as the soil moisture varies rapidly at water added intervals . But it became less sensitive to added water as the soil became deeper (30-70 cm). At the case of HYDRUS1D model the diversion from the observed soil moisture data became very small as we going deeper in the soil column.

Figures 3 shows that AquaCrop and HYDRUS1D models of the soil moisture simulation have better agreement with observed field data at the existence of plant represented by wheat with rain fed irrigation. Even AquaCrop model simulating data seem to be more accurate than that of bar soil (with or without irrigation), it give high diversion from the observed data till the mid time of growing season and less diversion after that. Comparing with HYDRUS1D model it still of poor fitness with the observed data, but HYDRUS1D give very good fitness along the time of growing season and going deeper with the soil column.

Figures 4 proves that both models (AquaCrop and HYDRUS1D) give more accurate data according to the observed data, comparing with the all of other agriculture application used before. This can be considered an encourage result of using both models for simulating soil water distribution under irrigated agriculture, but HYDRUS1D model still a very accurate model for simulating soil water distribution.

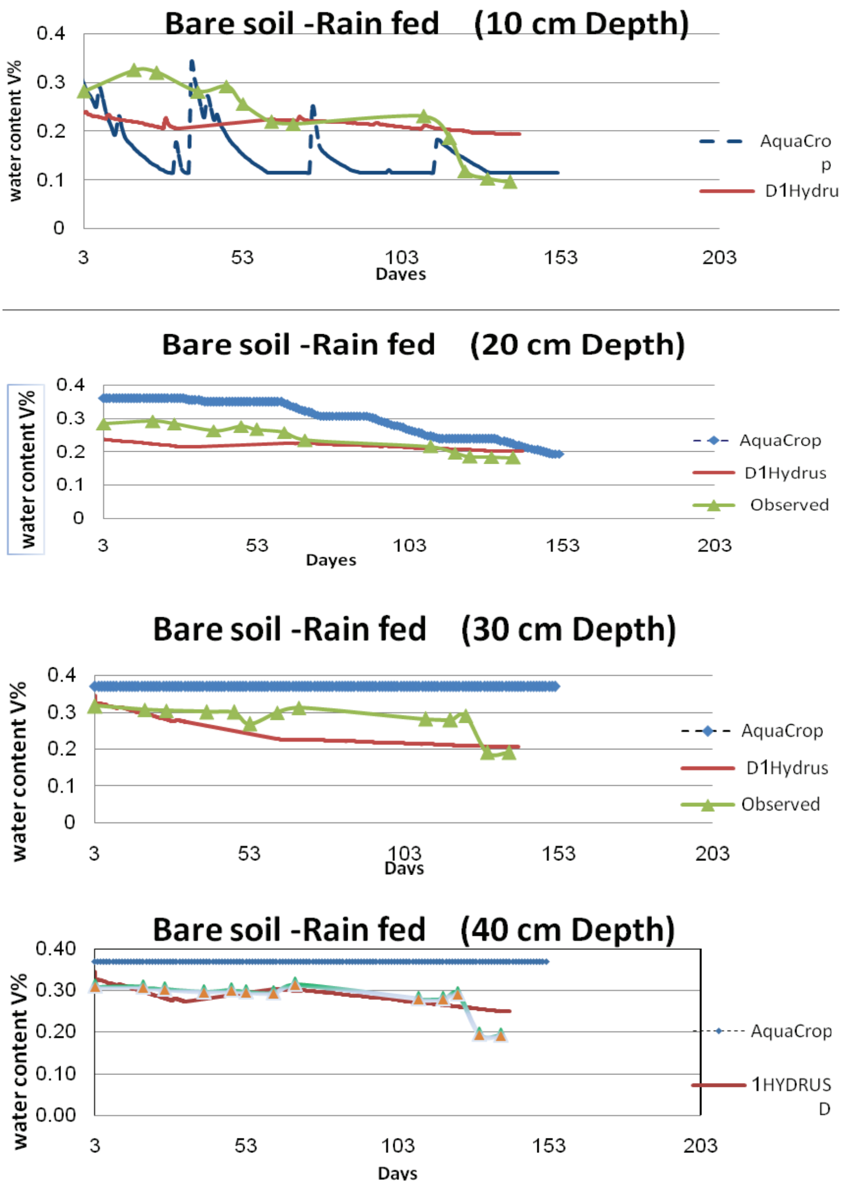

Fig. 1. Moisture content by volu me of Bar Soil at different depths with Rain fed type of irrigation, which observed form the field and modeled with AquaCrop and HYDRUS1D software.

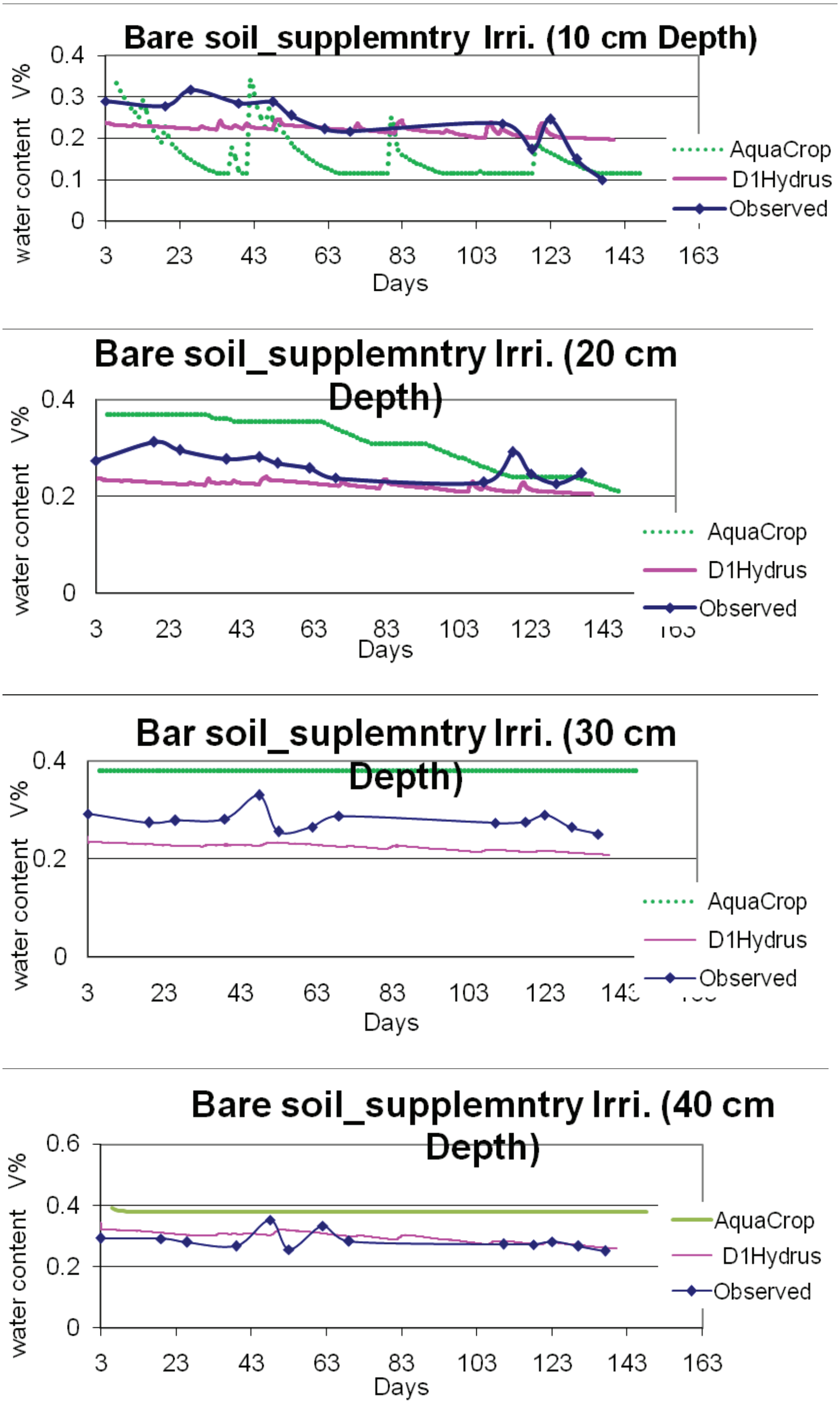

Fig. 2. Moisture content by volume of Bar Soil at different depths with supplementary type of irrigation, which observed form the field and modeled with AquaCrop and HYDRUS1D software.

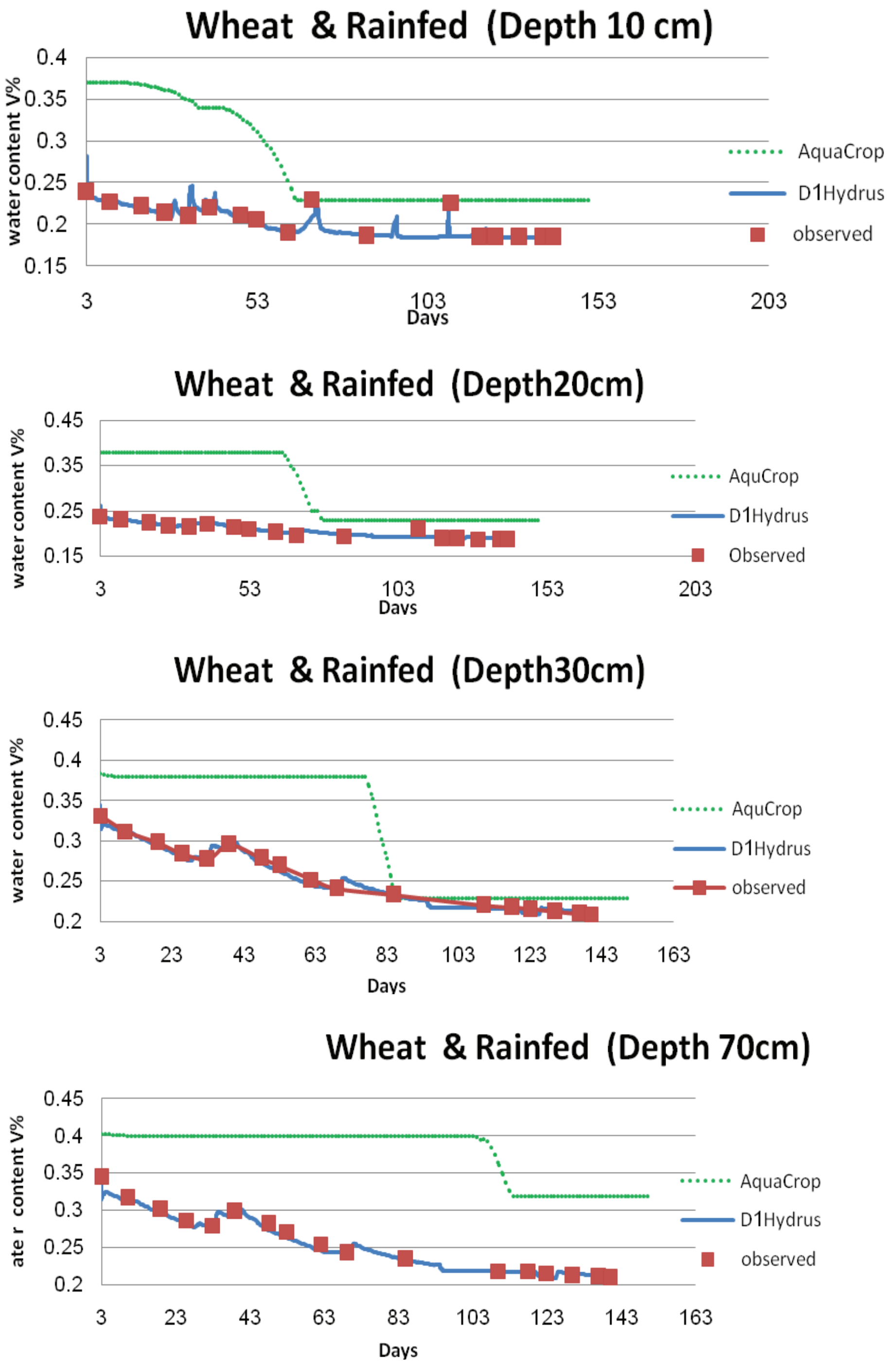

Figure 3. Moisture content by volume of wheat planted Soil at different depths with Rain fed type of irrigation, which observed form the field and modeled with AquaCrop and HYDRUS1D software.

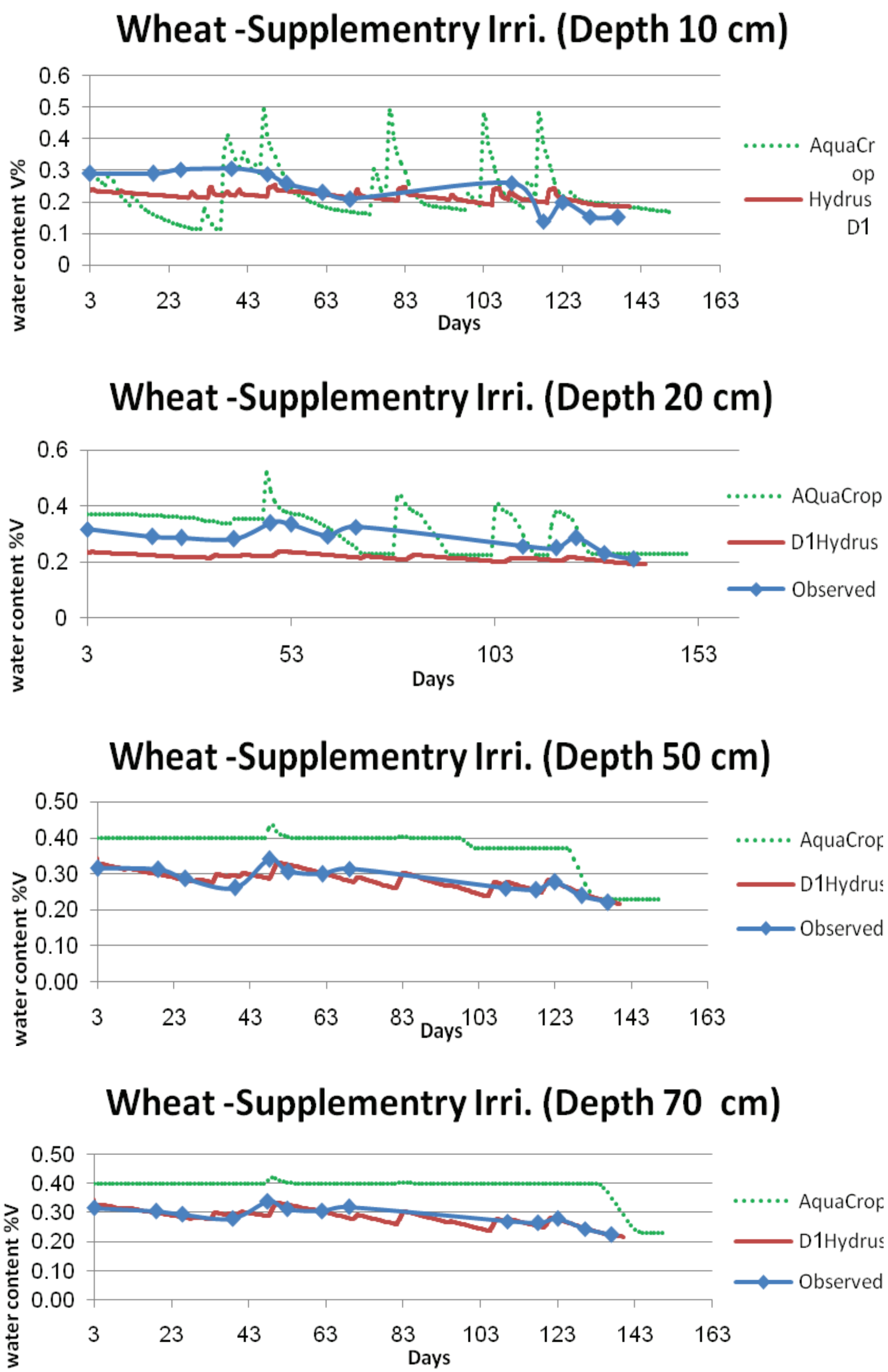

Fig. 4. Moisture content by volume of wheat planted Soil at different depths with supplementary type of irrigation, which observed form the field and modeled with AquaCrop and HYDRUS1D software.

4. CONCLUSIONS AND RECOMENDATIONS

- HYDRUS1D computer model can be used efficiently to model soil moisture distribution along time and depth with different type of water application.
- AquaCrop model is not an efficient model for simulating soil moisture distribution.
- AquaCrop model can be parameterized to give good simulation of the wheat growth in the field.
- Both HYDRUS1D and AquaCrop models can be integrated to have very good management of wheat especially at arid and semi arid areas.
- These two models have to be Parameterized with other field crops.

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