Simulation of Peanut (*Arachis hypogaea* L.) with Cropwat Model in Irrigation Condition and Rainfed

Ali Abdzad Gohari

Department of Water Sciences and Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran

**Corresponding author Email:** Abdzadgohari_a@yahoo.com

**Key words**

Irrigation
Rainfed
Cropwat model
Simulation
Peanut

**ABSTRACT**

The purpose of this study is to simulation of peanut with Cropwat model under Irrigated and Rainfed Conditions in order to provide information necessary in taking decisions is on irrigation management. The Cropwat model is an irrigation management and planning model simulating the complex relationships of on farm parameters the climate, crop and soil. This model was run for the specific weather conditions in the year 2009. Analysis suggests that from the second decade of august the values of soil moisture deficit remained higher than readily available moisture values due to which severe yield reduction in peanut crop occurred 45.6% in growth stage three of peanut vegetation season. The loss in total yield reduction was 43.6%. The total available moisture remained higher from readily available moisture and soil moisture deficit throughout the peanut vegetation season. Simulation for irrigated field of peanut crop is done using the criteria of fixed interval of 6 days with irrigation application of fixed depth of 40 mm from the first day of sowing. During the first 3- irrigation application 207.3 mm of water is lost, the first irrigation lost 1.1 mm, the second lost 102.5 mm and third irrigation lost 103.7 mm water. The relation of soil moisture deficit and readily available moisture is just like rainfed condition but having little differences in value as compared to rainfed condition simulation. The largest yield reduction 45.4% occurred in growth stage three of peanut vegetation season. Simulation estimated 39.4% yield reduction under irrigated condition.

**Introduction**

An irrigation management model simulating the complicated on farm crop-soil-climate phenomena will facilitate the estimate of the crop evapotranspiration, irrigation schedule, and agricultural water requirements with different cropping patterns for irrigation planning (Sheng-Feng Kuoa et al, 2001). Computer model simulation is an emerging trend in the field of water management. Water managers, irrigation agronomists, engineers and researchers taking keen interest in model simulation for the easier solution of problems faced by them (Nazeer, 2009). Crop simulation models are one set of tools that have been used to answer complex questions related to crop production, economics and environmental impact (Hoogenboom, 2000; Jones et al, 2003; Putto et al, 2013). Cropwat is a decision support system developed by the land and water development division of FAO for planning and management of irrigation. Cropwat is meant as a practical tool to carry out standard calculations for reference evapotranspiration, crop water requirements and crop irrigation requirements and more specifically the design and management of irrigation schemes. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions and the assessment of production under rainfed conditions or deficit irrigation. Cropwat facilitate the estimate of the crop evapotranspiration, irrigation schedule and agricultural water requirements with different cropping patterns for irrigation planning. The general objective of the study was to compare the simulation results of various options for water supply and irrigation management conditions and to estimate the yield reduction due to crop stresses under rainfed and irrigated conditions on peanut crop. These models can be used to optimize the allocation of irrigation water between different crops and or the distribution of water during the crop season (Bryant et al, 1992).

Peanut (*Arachis hypogaea* L.) is one of the most important and economical oilseeds in tropical and subtropical regions which is mostly grown due to its oil, protein and carbohydrates (Panwar, 2005). It is an annual shrub of Leguminosae family and Arachis genus which has a main straight root (Panj tandoust, 2008). The peanut seed is rich in edible oil and contains 43-55% oil and 25-28% protein (Maiti, and Ebeling, 2002). Supplying nutrients for plants in a normal way is essential to reach an optimum yield in agricultural production (Karimi et al., 2007). Peanut will need irrigation from pollination time until two weeks before ripeness. Thus, it is possible to increase production rate by selecting suitable irrigation method and optimum utilization of water supplies. Limitation of water supplies in different parts of Iran and its decrease in agriculture sector caused water being considered as most important reserve in agriculture.
Thus, it is necessary to follow certain measures in determination of plants required water. While water is a very important factor influencing of crop function but using other factors like fertilizer is also effective. Then it is tried that efficiency of utilization of water and other factors being maximum as much as possible and crop function rate being economically acceptable. Peanut is a crop whose drought resistance is due to its ability to maintain a viable root system during water stress. Water stress stimulates the growth of peanut roots into deeper soil. Optimum productivity of peanut requires adequate water during all stages of its physiological maturity (Reddy and Reddy, 1993), but there are some critical points in its growth stages (flowering and pod filling) that are very sensitive to soil water availability compared with early vegetative and late maturity (Reddy et al., 2003). Insufficient water during these critical points reduces seed yield substantially and fails to maximize water use (Reddy et al., 2003). In Iran, this product is grown in Golestan, Khouzestan and Gilan provinces. In Gilan, it is mostly planted in Astaneh Ashrafiyeh and also along Sepidroud river margin (Abdazad Gohari, 2012).

So the Cropwat is one of the computer models used to study climatic impact as well planning and management of irrigation scheduling. The objectives of this study were to apply Cropwat model to peanut crop in Astaneh Ashrafiyeh, Simulate results of various options for water supply and irrigation management conditions; and study yield losses under irrigated and rainfed conditions.

Materials and Methods
The experiment fields and Input Data
This experiment was conducted at the experimental field at Astaneh Ashrafiyeh, Gilan province, Iran (37° 16 N, 49 56 E; 3 m above sea level) in 2009 growing season. Mean precipitation during growing season was 166 mm. Calculations of the crop water requirements and irrigation requirements are carried out with inputs of climate, crop and soil data. The model carries out calculations for reference evapotranspiration, crop water requirements and irrigation requirements in order to develop irrigation schedules under various management conditions and scheme water supply. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules and the assessment of production under rainfed conditions or deficit irrigation. Cropwat is with Penman-Monteith method for calculation reference crop evapotranspiration. The development of irrigation schedules and evaluation of rainfed and irrigation practices are based on a daily soil-moisture balance using various options for water supply and irrigation management conditions. Scheme water supply is calculated according to the cropping pattern provided in the program (Smith, 1992). The potential evapotranspiration (ETo) was computed by Penman-Monteith Model (Allen et al., 1998). In this model, most of the equation parameters are directly measured or can be readily calculated from weather data. The equation can be utilized for the direct calculation of any crop evaporotranspiration (ETc). The FAO Penman-Monteith method to estimate ETc is:

\[
ET_c = \frac{0.408 \cdot (R_n - G) + \gamma \cdot \frac{900}{T+273} \cdot u_2 \cdot (e_v - e_a)}{+ \gamma \cdot (1+0.34 \cdot u_2)}
\]  
Equation 1

ETC: reference evapotranspiration (mm/day), Rn: net radiation at the crop surface (MJ/m.day), G: soil heat flux density (MJ/m.day), T: mean daily air temperature at 2 m height (°C), u2: wind speed at 2 m height (m/s), ev: saturation vapour pressure (kPa), ea: actual vapour pressure (kPa), ev-ea: saturation vapour pressure deficit (kPa), γ: slope vapour pressure curve (kPa/°C), and α: psychrometric constant (kPa/°C). The average climatic data and ETc calculated by model is presented in Table (1). Actual evaporotranspiration (ETc) was calculated for each crop via a water balance method, as in Equation (2).

\[
ET_c = I + P - D - R + DS
\]  
Equation 2

Where I: denotes irrigation depth (mm), P: rainfall (mm), D: drainage (mm), R: runoff (mm), DS: the change in soil moisture (mm). Daily values of crop coefficients were calculated for each crop using Equation (3).

\[
K_c = \frac{ET_c}{ET_o}
\]  
Equation 3

Where Kc is a crop coefficient, and ETc, ETo actual and reference crop evapotranspiration, respectively.

Climatic, Crop, Soil Data
The monthly average climatic data (Table1) of the year 2009 were used including maximum and minimum air temperature, relative humidity, wind speed, sunshine duration and rainfall. The department of water management provided this data. For this study, sets of standard Peanut crop data that are included in the program were used. Peanut crop was planted on 18th of May, respectively. The crop is assumed to be planted all at the same time and cover 100% of the
projected area. The model simulation requires of soil data, such as: heavy soil, medium soil and light soil which is fulfill by Cropwat automatically having soil data option.

Table 1. Average climatic data

<table>
<thead>
<tr>
<th>Month</th>
<th>Min Temp (°C)</th>
<th>Max Temp (°C)</th>
<th>Humidity (%)</th>
<th>Wind (km/day)</th>
<th>Sunshine (hours)</th>
<th>Radiation (MJ/m²/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>10.5</td>
<td>2.3</td>
<td>84</td>
<td>4</td>
<td>5</td>
<td>8.6</td>
</tr>
<tr>
<td>February</td>
<td>13.7</td>
<td>6.6</td>
<td>83</td>
<td>3</td>
<td>6.4</td>
<td>12.1</td>
</tr>
<tr>
<td>March</td>
<td>18.2</td>
<td>7</td>
<td>77</td>
<td>4</td>
<td>5.8</td>
<td>14.2</td>
</tr>
<tr>
<td>April</td>
<td>15.5</td>
<td>6.9</td>
<td>81</td>
<td>4</td>
<td>5.9</td>
<td>16.9</td>
</tr>
<tr>
<td>May</td>
<td>23.6</td>
<td>14.2</td>
<td>77</td>
<td>6</td>
<td>4.3</td>
<td>16.1</td>
</tr>
<tr>
<td>June</td>
<td>27.9</td>
<td>18.8</td>
<td>74</td>
<td>7</td>
<td>3.6</td>
<td>15.6</td>
</tr>
<tr>
<td>July</td>
<td>30.8</td>
<td>20</td>
<td>66</td>
<td>7</td>
<td>3.4</td>
<td>15</td>
</tr>
<tr>
<td>August</td>
<td>30.6</td>
<td>21.4</td>
<td>67</td>
<td>7</td>
<td>3.6</td>
<td>14.2</td>
</tr>
<tr>
<td>September</td>
<td>26.2</td>
<td>17.9</td>
<td>80</td>
<td>5</td>
<td>4.5</td>
<td>13.4</td>
</tr>
<tr>
<td>October</td>
<td>23.2</td>
<td>14.4</td>
<td>82</td>
<td>5</td>
<td>3.6</td>
<td>9.8</td>
</tr>
<tr>
<td>November</td>
<td>22.2</td>
<td>13.2</td>
<td>79</td>
<td>4</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>December</td>
<td>22</td>
<td>13</td>
<td>77</td>
<td>5</td>
<td>4.6</td>
<td>7.6</td>
</tr>
</tbody>
</table>

Results and Discussions

The decreasing of \( \text{ET}_o \) values is due to increase in rainfall (Figure 1). The crop water requirement graph show that peanut water requirement is increasing with the passage of time and required peak amount of water at the growing and developmental stage. The graph of irrigation water requirement remained below than the crop water requirement throughout the vegetation season of peanut at both plots causing severe yield reduction.

![Figure 1. Simulation of Cropwat model for ET\(_o\) (mm/day) and rainfall (mm)](image)

![Figure 2. Simulation of Cropwat model for coefficients (\(K_c\)), Irrigation requirement and effect rain, in peanut](image)
Crop coefficients ($K_c$)

Crop coefficients ($K_c$) were determined by dividing the measured actual evapotranspiration by reference crop evapotranspiration, as calculated based on the modified Penman equation. Coefficients ($K_c$) values were determined at during the growth season. These values changed at different periods due to natural climatic conditions. Therefore, this work designed a mean crop coefficient curve for different growth periods. In Figure (2) Based on the field experiments and water management data, the Cropwat model simulated the on-farm for amounts coefficients ($K_c$). Irrigation requirement and effect rain, for peanut crops is shown.

Simulations

The steps in the simulation were Cropwat model was run for peanut crop with the monthly average climatic data for the two plots and different scheduling criteria. The rainfed (Plot A) is simulated only on rainfall command while the irrigated (Plot B) was simulated with fixed amount (25 mm) and fixed interval (6 days). Analyzed the model results and select the most suitable irrigation schedule options.

Crop evapotranspiration ($ET_c$) and irrigation water requirement (IWR)

The simulated value of crop evapotranspiration ($ET_c$) and irrigation water requirement (IWR) for the peanut crop district is shown in Figure (3). The crop evapotranspiration is at peak (9.3 mm/dec), slightly reduced at growing stage (7.5 mm/day), and then at mid stage (7.8 mm/day) and at last stage it reaches to 3.2 mm/day.

Total Available Moisture (TAM) Readily Available Moisture (RAM) and Soil Moisture Deficit (SMD)

The model calculates the Crop Water Requirements using the equation:

$$CWR=ET_c \times K_c$$

This means that the peak CWR in mm/day can be less than the peak $ET_c$ value when less than 100% of the area is planted in the cropping pattern.

Total Available Moisture in the soil for the crop during the growing season is calculated as Field Capacity minus the Wilting Point times the current rooting depth of the crop.

$$TAM = (FC\% - WP \%) \times D_{root}$$

Readily Available Moisture (RAM) is calculated as:

$$RAM = TAM \times MAD$$

Where MAD is the depletion fraction as defined in the crop coefficient ($K_c$) file, to avoid crop stress, the calculated soil moisture deficit should not fall below the readily available moisture. The criteria, which create, distinguish between crop water requirement and Crop water requirement is the amount of rainfall. Simulation under rainfed condition is done for peanut sown; depend only on rainfall water, where there is no other source of irrigation. So the calculated soil moisture deficit shows the effect of rainfall only. The values of soil moisture deficit are very low for the first three-four decade during peanut vegetation, follow increasing up, when it reaches to cross the limit of readily available moisture in first decade of august. From the second decade of august the values of soil moisture deficit remained higher than RAM.
values due to which severe yield reduction in peanut crop occurred 45.6% in growth stage three of Peanut vegetation season. The loss in total yield reduction was 43.6% (Table 2). The total available moisture remained higher from RAM and SMD throughout the peanut vegetation season. Simulation for irrigated field of peanut crop is done using the criteria of fixed interval of 6 days with irrigation application of fixed depth of 40 mm from the first day of sowing (Figure 4, 5). During the first 3-irrigation application 207.3 mm of water is lost, the first irrigation lost 1.1 mm, the second lost 102.5 mm and third irrigation lost 103.7 mm water. The main cause for losing of irrigation water is the bare soil. The relation of soil moisture deficit and readily available moisture is just like rainfed condition but having little differences in value as compared to rainfed condition simulation. The largest yield reduction 45.4% occurred in growth stage three of peanut vegetation season. Simulation estimated 39.4% yield reduction under irrigated condition (Table 3). Total available moisture is same as in rainfed condition because the soil characteristic is same for irrigated as well rainfed plots.

![Figure 4. Simulation of peanut under rainfed condition](image)

![Figure 5. Simulation of peanut under irrigated condition](image)

<table>
<thead>
<tr>
<th>Date</th>
<th>TAM (mm)</th>
<th>RAM (mm)</th>
<th>Total Rain (mm)</th>
<th>Effect Rain</th>
<th>ETc (mm)</th>
<th>ETc/ETm (%)</th>
<th>SMD (mm)</th>
<th>Interval (day)</th>
<th>Net Irrigation (mm)</th>
<th>Lost Irrigation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>102.9</td>
<td>37.8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

* Yield Reduction:
- Estimated yield reduction in growth stage # 1 = 0.0%
- Estimated yield reduction in growth stage # 2 = 22.5%
- Estimated yield reduction in growth stage # 3 = 45.6%
- Estimated yield reduction in growth stage # 4 = 19.0%

- Estimated total yield reduction = 43.6%

### Table 3. Simulation of Peanut under irrigated condition (Plot B).

<table>
<thead>
<tr>
<th>Date</th>
<th>TAM (mm)</th>
<th>RAM (mm)</th>
<th>Total Rain (mm)</th>
<th>Effect Rain</th>
<th>ETc (mm)</th>
<th>ETc/ETm (%)</th>
<th>SMD (mm)</th>
<th>Interval (day)</th>
<th>Net Irrigation (mm)</th>
<th>Lost Irrigation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16/5</td>
<td>39</td>
<td>17.5</td>
<td>0</td>
<td>0</td>
<td>1.1</td>
<td>100</td>
<td>1.1</td>
<td>1</td>
<td>1.1</td>
<td>0</td>
</tr>
<tr>
<td>24/8</td>
<td>104</td>
<td>50.7</td>
<td>0</td>
<td>0</td>
<td>0.1</td>
<td>40.1</td>
<td>102.5</td>
<td>100</td>
<td>102.5</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>0</td>
<td>0</td>
<td>119</td>
<td>43.7</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td>103.7</td>
<td>0</td>
</tr>
</tbody>
</table>

* Yield Reduction:
- Estimated yield reduction in growth stage # 1 = 0.0%
- Estimated yield reduction in growth stage # 2 = 21.6%
- Estimated yield reduction in growth stage # 3 = 45.4%
- Estimated yield reduction in growth stage # 4 = 15.5%

- Estimated total yield reduction = 39.4%

### Conclusions

The Cropwat model can appropriately estimate the yield reduction caused by water stress and climatic impacts which makes this model as a best tool for irrigation planning and management in peanut. The simulation results analysis suggest that in both condition rainfed and irrigated, the largest yield reduction occurred in the stage three (developmental stage) due to increasing of readily available moisture, irrigation at this stage can reduce the chance of yield reduction appropriately.
References
Naseer M, 2009. Simulation of maize crop under irrigated and rainfed conditions with Cropwat model. ARPN journal of agricultural and biological science. vol.4, no.2.