Estimation of evapotranspiration and irrigation scheduling of lentilusing CROPWAT 8.0 Model for Anantapur District, Andhra Pradesh, India

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ABSTRACT

To achieve effective water allocation and planning, the information about Lentil crop water requirements, irrigation withdrawals, soil types and climate conditions were gathered from the study area i.e. Anantapur district of Andhra Pradesh (A.P). The main objectives of the study area were to estimate the Lentil crop water requirement (i.e., evapotranspiration) and deciding the proper sowing time in semi-arid agro-climatic conditions. The CROPWAT 8.0 was used to estimate the climatic water deficit, net irrigation requirement (NIR) and gross irrigation requirement (GIR) under different rainfed and irrigated conditions with six different growing dates with aninterval of 10 days. The results showed that the best sowing dates were last week of September to 1st week of October, which gives thebest utilization of rainfall as effective rainfall. The net and gross irrigation requirement (NIR and GIR) varied from a minimum to maximum as 69.7 mm, 110.3 mm, 78.2 mm, 119.4 mm, 114 mm and 165.9 mm; respectively for all sowing dates. Thus by adopting a proper sowing date and irrigation scheduling criteria, it is possible to save 49.7 mm of water as NIR for theearly sown crop.

INTRODUCTION

It is important that the water requirements of crops are known at different management levels within the irrigated area to accomplish effective irrigation management. The crop water requirements are met from the effective rainfall, irrigation water applied and the available soil moisture (Reddy, 2012). Assuming that the change in available soil moisture before and after crop seasons is negligible, the water requirements of the crop are met from effective rainfall and irrigation water. The potential evapotranspiration $ET_P$of a crop is the volume of water required by it to meet its evapotranspiration requirements. The crop irrigation water requirement, therefore, consists of potential evapotranspiration, $ET_{P,}$ minus the effective precipitation.

Climatic water demands, that govern the crop water requirement, are highly location specific hence, required to be established with high accuracy and precision. Depending upon the climatic water demand alternatively referred as reference evapotranspiration (ET_o) all other components of root zone water balancemay be determined accurately (Peter, 2005). The present study was attempted to estimate the components of root zone water balance using standard methodologies with FAO, CROPWAT model 8.0 for Lentil (*Lens culinaris*). Lentil is a pulse crop predominantly grown in rainfed conditions with alow yield in our country (Singh and Bhatt, 2013). Lentil name was derived from 'Lens' having the

'lens' shaped seeds, is one of the important and most nutritious *rabi* pulses (Kadam *et al.,* 2012). Lentil is a typically dry land crops, can be grown under irrigation with careful water management. Excess water in lentil crops can cause problems including delayed maturity, increased disease, and lower yields. It has the potential to cover the risk of rainfed farming. It is also used as a cover crop to check the soil erosion in problem areas (Othman *et al.,* 2016; Donna, 2016). Lentil seeds also provide a source of starch for textiles and printing. Lentil residues form important livestock feed. Lentil flour is used for thickening of soups. It is mixed with wheat flour in bread and cake production.

MATERIALS AND METHODS

In order to achieve the objectives set for the present study, experiments were carried out in the laboratory as well as in the field of Precision Farming Development Centre (PFDC), Water Technology Centre (WTC), ICAR-Indian Agricultural Research Institute (IARI), New Delhi. (Latitude 28°37'30" - 28°30'0" N, Longitude 77°8'45" -77°10'24" E and AMSL 228.61 m) during October to February two years (2013-14, 2014-15).

Study area

The Anantapur district is located in the northern region of the state of Andhra Pradesh district in the Rayalaseema region, on the southern part of India (Fig. 1).Thestudy area comprising 2200 sq km extends from Anantapur town in the south to border of Kurnool and Kadapa districts in NEand E respectively in Andhra Pradesh State.The total geographical area it is the largest district of Andhra Pradesh spanning an area of 19,130 square kilometres. The study area is located at

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14°30' - 15°30' and E longitudes 77°45' - 78°10'.An average elevation is about 624 m above mean sea level. This region is under semi-arid climate predominated by hot and dry weather throughout the year. Average annual rainfall of Anantapur district is about 582 mm (Handbook of Statistics: 2010-11) and is drained by 2 major rivers Pennarand

Fig. 1: Study area *Ananthapur* district. Andhra Pradesh, India

Chitravatirivers with their tributaries drain the area. Except forPennar all other rivers, streams have seasonal flow and are ephemeral. Agriculture is the principal occupation of the people and is the backbone of therural economy. Majority of agricultural activity is dependent on groundwater, as surface water resources like minor irrigation projects or tanks are almost defunct due to continuous low rainfall.

Climatic and rainfall-runoff characteristics

The growth of lentil crop is adversely affected at temperatures above 27ºC. Hence, it is grown as a winter season crop in semi-arid tropics. The present study area has average minimum and maximum temperature, relative humidity, sunshine hours and wind speed as 21.5°C, 34.1°C, 54.4 %, 7.8and 234.8 km/day;respectively (Table 1). Lentils require a minimum of 350 mm and maximum of 550 mm rainfall.In the higher rainfall areas, good drainage is essential. Waterlogging will have a great effect on yields and disease spread. Drought and severe or prolonged hot weather can cause loss in yields through pod cracking. The study area receivesan average low rainfall around 400-450 mm.Effective rainfall was computed according to the "USDA Soil Conservation Service Method" formula.(FAO, 1998; FAO, 2009) using FAO CROPWAT 8.0 model by following equations 1 and 2.

$$\text{Rainfall excess } Pe = \frac{(P * (125 - 0.2 * 2 * P))}{125} \quad \text{if rainfall} \leq \frac{250}{3} \; mm \qquad [1]$$

$$\text{Rainfall excess} = \frac{125}{3} + 0.1 * P \quad \text{if rainfall} \geq \frac{250}{3} \; mm \qquad [2]$$

Where, P = Total rainfall (mm)

Table 1: Average long-term climatic parameters and the estimated reference evapotranspiration ETo using the FAO-Penman Monteith equation of study area (Anantapur, A.P.) for Lentil crop.

Month	Min Temp, (^{o}C)	Maxi Temp, (^{o}C)	RH, (%)	Wind speed, (km/day)	Sunshine Hours	Rainfall, (mm)	Effective rainfall, (mm)	ETo, mm/day
January	17.0	31.7	54	187	9.4	1.8	1.8	4.88
February	19.7	34.8	50	195	9.7	0.5	0.5	5.84
March	21.9	37.2	43	202	9.9	6.9	6.4	6.88
April	24.7	38.7	40	215	9.8	21.4	19.6	7.60
May	25.7	39.0	42	296	9.4	48.7	43.8	8.51
June	24.3	35.6	51	383	7.5	82.1	64.6	7.78
July	23.2	33.2	59	372	5.2	155.7	100.5	6.28
August	22.8	32.7	62	321	5.4	169.2	108.4	5.76
September	22.4	32.2	64	223	6.5	177.2	114.6	5.20
October	21.4	32.1	63	133	7.0	114.4	88.0	4.51
November	18.7	31.5	62	138	8.2	23.0	21.0	4.35
December	16.7	30.1	63	153	7.8	10.0	9.2	3.98
Total Rainfall (All good year)						811.3	578.7	5.90

Soil data

For any crop growth, the soil will pay major role for crop production and productivity. The major soil types raised on light loams and alluvial soils in upper India, and on well-drained, moderately deep, light black soils, loam soils in Madhya Pradesh, Maharashtra and some parts of Andhra Pradesh (Shah *et al.,* 2015) (Some districts of A.P. like Kadapa, *Kurnool and Chittoor*). It is also grown on low lands, poor soils. The crop can withstand moderate alkalinity however, it can't tolerate waterlogging. Soil should be made friable and weed free so that seed could be placed at a uniform depth. In case of light soils, less tillage is required to prepare an ideal seed-bed.

In heavy soils, one deep ploughing followed by 2-3 cross harrowing should be given. After harrowing, the field should be levelled by giving a gentle slope for easy irrigation. There should be proper moisture in the soil at the time of sowing for proper germination of seeds.

Calculation of crop water requirements

The calculation of Lentil crop water requirements was done using FAO Penman-Monteith equation. The basic formula for the calculation of crop evapotranspiration given in the following equation

$$ET_{crop} = K_c \times ET_o \quad [3]$$

Where, ET_{crop} is the water requirement of a given crop in mm

per unit of time (mm/day, mm/month or mm/season)., K_c is the crop factor, ET_o is the reference crop evapotranspiration in mm per unit of time (mm/day).ET_o is calculated by FAO-Penman-Monteith equation.

FAO Penman-Monteith equation

The FAO Penman-Monteith method is used to estimate ET_o based on the original Penman-Monteith equation and the equations of the aerodynamic and surface resistance can be given as in the equation (FAO, 1998; FAO, 2009; Shah *et al.*,2015).

$$ET_o = \frac{0.408\Delta(R_n-G)+Y\frac{900}{T+273}U_2(e_s-e_a)}{\Delta+Y(1+0.34U_2)} \qquad [4]$$

Where, ET_o = reference evapotranspiration (mm/day); R_n= net radiation at the crop surface (MJ.m^{-2}.d^{-1}); G = soil heat flux density (MJ.m^{-2}.d^{-1}); T = mean daily air temperature at 2 m high (°C); u_2 = wind speed at 2 m high (m.s^{-1}); e_s = saturation vapor pressure (kPa); e_a = actual vapor pressure (kPa); e_s-e_a = saturation vapor pressure deficit (kPa); Δ = slope vapor pressure curve (kPa.°C^{-1}); Y= psychrometric constant (kPa. °C^{-1}). The equation uses standard climatological records of solar radiation (i.e. sunshine), air temperature, humidity and wind speed. In other hand the following imperials namely, Evaporation pan, Balneycriddle, Thornthwaite formula were also used for estimation of crop water requirements using the different climatic parameters based on the suitability and availability of data base.

Selection of crop factor K for crops

In order to obtain the crop water requirement (ET_{crop}) the reference crop evapotranspiration (ETo) must be multiplied by the crop factor (K_c). The crop factor (crop coefficient) varies according to the growth stage of the crop. There are four growth stages to distinguish: (i). The initial stage: when the crop uses little water; (ii). The crop development stage, when the water consumption increases; (iii). The midseason stage, when water consumption reaches a peak; (iv). The late-season stage, when the maturing crop once again requires less water (FAO, 1998; FAO, 2009; Shah *et al.,* 2015).

Irrigation scheduling and water requirement of Lentil crop

The efficiency of water in agricultural production is generally low. Only 40 to 60 % of the water is effectively used by the crop, the rest of the water is lost in the system or in the farm either through evaporation runoff or by percolation into the groundwater. Irrigation scheduling, if properly managed can offer a good solution to improve water efficiency on the farm. Irrigation scheduling involves deciding when and how much water to apply to a field. Good scheduling will apply water at the right time and in the right quantity in order to optimize production and minimize adverse environmental impacts. Bad scheduling will mean that either not enough water is applied or it is not applied at the right time, resulting in underwatering, or too much is applied or it is applied too soon resulting in overwatering(Shah *et al.,* 2015; Othman *et al.,* 2016).

Under or overwatering or deficit conditions can lead to reduced yields, lower quality and inefficient use of nutrients. In the present study, the irrigation scheduling makes sure that

water is consistently available to the plant and that it is applied according to crop requirements. The irrigation schedulewas prepared using CROPWAT 8.0 model, irrigation at 100% critical depletion, irrigation at fixed interval per stage and method of irrigation application, refill soil moisture content to 100% to field capacity. For the present study the standard procedure was followed for irrigation scheduling of Lentil crop under most acceptable criterion.

Calculation of irrigation water requirements based on climatic parameters

Net irrigation water requirement (NIWR) or (NIR) is the quantity of water necessary for crop growth. It is expressed in mm per year or in m^3/ha per year (1 mm = 10 m^3/ha). It depends on the cropping pattern and the climate.

The FAO's CROPWAT software (version 8.0) was used to compute NIWR for the study area and the model was run for six different scenarios of sowing dates; six sowing dates were simulated (2 each) for early sowing, normal sowing and late sowing date conditions. Gross irrigation water requirement (GIWR) is the amount of water to be extracted (by diversion, pumping) and applied to the irrigation scheme. It includes NIWR plus water losses: The GIWR in mm was given by the following equation.

$$GIWR \quad \frac{NIWR}{E} \qquad [5]$$

Where,E is the global efficiency of the irrigation system.

RESULTS AND DISCUSSION

The study area has received annual rainfall around 400-582 mm. The maximum rainfall is received during the months from August to Novemberas shown in (Table 1). The results showed that more amount of water results into effective rainfall, this can be used for crop growth (Kumar and Rao, 2017). The excess water can be stored as infiltration in the show soil depth that can be used for crop production when there is theabsence of rain or irrigation supply or deficit irrigation in the field.(Fig. 2 and Fig. 3) shows that the six different sowing dates with aninterval of 10 days sowing periods namely; earliest sowing dates start from 1st September, early sowing date, normal sowing date-1, normal sowing date-2, late sowing and latest sowing up to 20 October. The results speak that effective rainfall can be maximum during the crop growing periods due to field preparation as results of less runoff.

The sowing date and period play vital role in the crop production and yield as well as the productivity of thecrop.It mainly depends on the Antecedent soil Moisture Condition and soil moisture storage in the soil root zone. The results
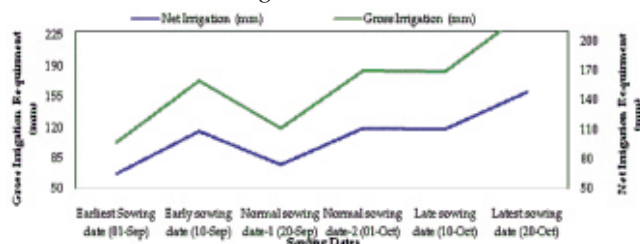

Fig. 2: Relation between gross and net irrigation requirement of Lentil crop (GIR and NIR) based on different sowing dates.

speak that the maximum utilization of rainfall is on the normal sowing dates that are 1st October to 10 October. The earliest or latest sowing date'sresults into less efficiency of rain due to more runoff and rainfall periods.

Establishment of irrigation water requirements of Lentil crop
Based on the effective rainfall data in the study area, irrigation water requirements can be calculated from the difference between effective rainfall and the total water requirement.The net irrigation and gross irrigation requirement are in increasing orderthrough growing period of thecrop (Machiwal and Jha, 2017). It mainly depends on the growth stages of Lentil, crop coefficient, variety, soil type etc. The figure shows the NIR and GIR during the six different sowing date's starts from September 1st to October 20 with aninterval of 10 days period. The (Fig.3) shows the actual water requirement for the lentil crop during the crop period and the moisture deficit.
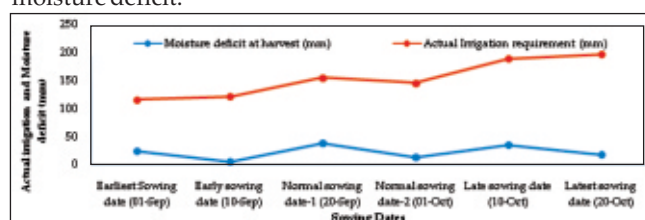

Fig. 3: The relation between actual irrigation requirement and moisture deficit at harvesting time of lentil crop.

Water budgeting of Anantapur region for different scenario
The water budgeting of the region for thedifferent scenario of different years was estimated using CROPWAT 8.0. The gross irrigation was 154.95 mm; net irrigation was 109.5mm; actual
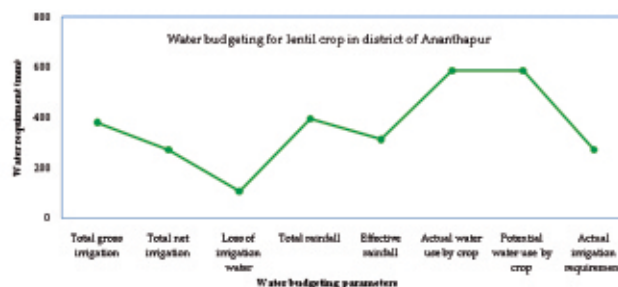

Fig. 4: Water budgeting for the *Anantapur* region Lentil crop

water use by crop 243.5 mm potential water use by crop 243.5 mm and the efficiency of application of irrigation was calculated as 68.11% respectively (Fig. 4).

CONCLUSIONS
An attempt was made to estimate the crop water requirement, net irrigation requirement (NIR) and the gross irrigation requirement (GIR) and sowing dates of Lentil crop (*Lens culinaris*) grown in thesemi-arid climatic region of *Anantapur* district of Andhra Pradesh. This district receives very low scanty rainfall varies from 400-450 mm. The results showedthat 5.90 mm/day under the six different crop sowing dates starting from 1st September to 20 October with alag of 10 days period.

The results revealed that the less NIR, GIR requirement was observed under normal date-1 and early sowing dates i.e. 69.7 mm to165 mm and 98.7 mm to 230.8 mm respectively. The study concluded that the Lentil crop,one of the highest nutritional crop, needs relatively less water requirement and it can tolerate the water scarcity so that the normal dates for sowing are mid-September to mid-October.

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