



Statistical analysis of water deficiency and crop water requirement of cotton in northern Maharashtra region

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Abstract

Maharashtra is one of the leading producers of cotton in India. But due to water scarcity the cotton production is fluctuating very much due reduced actual rainfall and consequently decrease in water table in each year. This study is conducted around northern Maharashtra region by collecting data for minimum and maximum climatic temperature and rainfall data of 2010-2016. To quantify the water need of cotton crop it is essential to calculate the Evapotranspiration potential using Blaney – Criddle equation and water deficiency ratio to consider the irregularity in deficiency as well as availability of rain water in this assured rainfall zone. The information about Water availability and deficiency in particular developing stage for crop will be very beneficial to suggest proper and correct irrigation supplements.

Keywords: crop water requirement, water deficiency ratio

1. Introduction

Water availability is the most essential parameter for sustaining agriculture as it is a back bone of our Indian economy. It is necessary to maintain sufficient water availability for getting good yield of crop and controlling inflations rates. Maharashtra is the leading producer of cotton crop and almost 50.38 % of land area of Jalgaon district is under cotton cultivation and many of the populations livelihood are depends on it. Whole part of North Maharashtra covered by the district Jalgaon which belongs talukas like Bodwad, Jamner, Dharangaon, Raver, yawal, Muktainagar Chopda are the leading producers of cotton in this region. All of this area is assured rainfall fed zone which was one of the strength of these region and agriculture totally depends on actual annual rainfall. While limited irrigation facilities is one of the major weakness, only 32.1 % of area is irrigated while rest of the areas are assured rainfall fed zone. But Maharashtra state has been number one deficit state in country at 52 % deficit in rainfall for a long time. According to meteorological report northern part of Maharashtra region reported actual rainfall of 436.3mm from normal value of 554.8mm, there was -118.5mm rainfall deficit reported in current year 2017. On the other hand according to records of 2014, the Jalgaon district water table depleting 2-3. By taking average of last three years the district average yield of cotton crop 460 kg/hac from the total cultivable land of 3915.55 hacs. This would require growth rate of approximately 5.8% to achieve the expected yield per year. Therefore it is essential to design proper irrigation scheduled to get good yield with minimum amount of irrigation water.

To quantify the level of Irrigation supplements it is first necessary to find the full ETcrop requirements. This study determines the crop water requirements (Et crop) and water deficit ratio (WDR) of cotton crop grown in north Maharashtra region during the total length of growing period

of 180 days to suggest the supplemental irrigation in this semi-arid zone which define the practice of applying small amounts of irrigation water to winter crops that are normally grown under rain-fed conditions^[1]. Determinations of ETcrop using Blaney- Criddle equations^[2] and WDR for a cotton crop from growing period of June-November from last eight years is done by collections of various data of actual rainfall and maximum and minimum temperature from year 2010 – 2016 during the sowing time of June to the harvesting period of November.

The cotton yield per unit area is fluctuating very much because of variations in actual rainfall from normal value and also increase in climatic temperature each year. Regardless of the type of irrigation method used, it is essential to develop scientific irrigation scheduling procedures^[3]. For the proper irrigation scheduling it is important to find out the total water demand by the crop plant in relation to supply from soil, if water supply is limited from soil then plants starts wilting 4 (Bhaskar *et al.* 2004)^[20]. The peak flower to peak boll development stage are very sensitive for water availability and if irrigation is not provided at this stage the cotton yield affect badly by about 5-8q/ha depending upon soil, genotype and management level 5 (Bhaskar *et al.*, 1998)^[19] Therefore determining Etcrop and water deficit ratio analysis are helpful in recommendations of proper and protective irrigations supplements. To Provides right irrigation supplements, we need precise knowledge of crop response to drought stress for each of the growth stages⁶ (Kirda *et al.*, 1999)^[21, 9]. In addition, correct application of irrigation water requires a thorough assessment of the economic impact of the yieldreduction caused by drought stress⁷ (English, 1990; 8 English and Raja, 1996; 9 Sepaskhah and Akbari, 2005; 10 Sepaskhah *et al.*, 2006)^[5, 10, 22, 23, 11, 12, 23, 24].

The objectives of the study is to estimate the average crop water need (ETcrop) and average water deficit ratio of cotton

crops during total LGP and also to recommend the average supplements of irrigations facilities according to different stages of crop growth.

References should be like this ^[1, 2, 3].

2. Materials and Methods

2.1 Geographical Information

North Maharashtra region is located at 20-21°N and 74.05-76.28 E elevated at 175-325 m altitude. The annual average temperature is approximately 35- 38°C having aridity index in the range 0.2- 0.4 which was calculated from taking ratio of annual precipitation and evapotranspiration potential mm/day of last eight years.

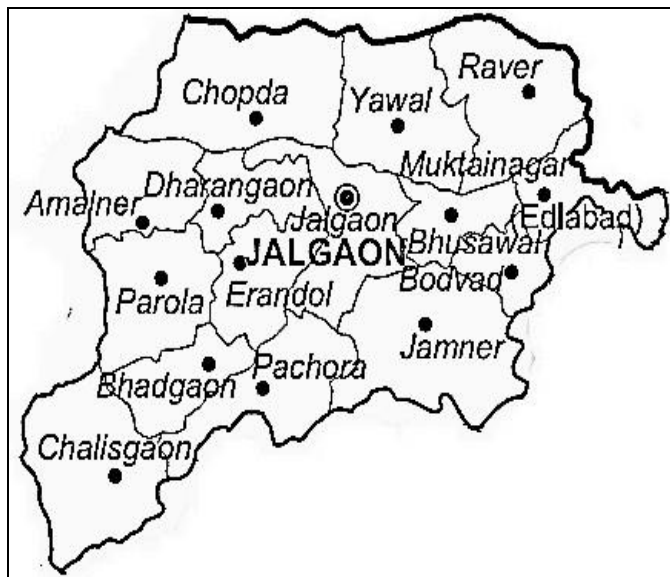


Fig 1

2.2 Determination of crop water need- ETcrop

The ETcrop has been determined by crop co-efficient method 12 (Dorenbos *et al.* 1977 ^[26], FAO, irrigation and drainage paper 24) of multiplying crop factor or coefficient Kc (given in Table-1) with that of daily evapotranspiration potential (ETo).

Table 1: crop coefficient at different growth stages of cotton

Crop factors Kc for different growth stages of cotton		
Initial stage	30 days	0.45
Developmental stages	50 days	0.75
Mid-Season stages	55 days	1.15
Late season stages	45 days	0.75
Average	180 days	0.82

The values of daily ETo in each year from 2010 to 2016 during total LGP is calculated by using Blaney- Criddle 2 (Borrelli *et al.* 1981) equation which only requires maximum and minimum temperature data,

$$ETo = p (0.46 \times T.I + 8) \tag{1}$$

Where p is mean daily % of annual day time hour for 20-21°N of June to month of November is shown below,

Table 2

Jun	July	Aug	Sep	Oct	Nov
.30	.30	.29	.28	.26	.25

(FAO, irrigation and drainage paper 24).

Thermal index (T.I) can be calculated by taking average of the maximum and minimum temperature at each month. (T.I) = Tmax +Tmin /2

Maximum and minimum temperature data has been recorded from Time and date AS, Norway. Shown in table-3.

2.3 Determination of water deficit ratio (WDR)-

For Calculation of Water deficit ratio the information about average rainfall and crop water need (ETcrop) for different growing stage of cotton is required and it is calculated using formula,12 (Qushenglia, *et al.* 2004)

$$WDR= 100 \times (ETcrop-P)/ETcrop \tag{2}$$

2.4 Data Collections

2.4.1 Maximum and minimum temperature during total length of growing period from the month of June to November of last eight years is shown in table. 3

Table 3

	June T.i (°c)	July T.i (°c)	August t.i (°c)	September t.i (°c)	October t.i (°c)	November t.i (°c)
2010	36	28	25	26	27	19
2011	33	26	25	25	27	22
2012	30	26	25	25	27	22
2013	27	25	24	26	25	22
2014	32	27	26	25	27	24
2015	29	26	25	27	28	25
2016	31	26	24	26	25	23

Source: <http://www.timeanddate.com>

2.4.2 The record of annual rainfall of North Maharashtra region of last eight years has been

Collected from, National Information Centre of Pune, Government of Maharashtra.

Table 4: Source: Rainfall Recording and Analysis, Department of Agriculture,Pune

Year	Rainfall per month during season in mm				
	June	July	August	September	Total Rainfall /Year
2010	94	296.8	238.5	118.3	747.6
2011	29.7	208.4	259.6	110.4	608.6
2012	20.8	181.5	102.5	86.2	391.0
2013	195.0	249	208	182	834
2014	20.4	260.6	131	199	611.0
2015	114.1	42.9	127	134	418
2016	91.8	240.0	113.5	176.9	621.7

3. Results

Reference evapotranspirations during total length of cotton growing period of last eight years has shown in table.5

Table 5: Calculated evapotranspiration potential from 2010-2016 during total LGP.

Year	June (ETo mm/day)	July (ETo mm/day)	August (ETo mm/day)	September (ETo mm/day)	October (ETo mm/day)	November (ETo mm/day)	Total LGP (ETo mm/day)
2010	7.37	5.99	5.65	5.46	5.31	5.10	5.81
2011	6.95	5.98	5.65	5.46	5.3	4.53	4.62
2012	6.54	5.98	5.65	5.46	5.30	4.53	4.56
2013	6.12	5.85	5.52	5.58	5.07	4.53	4.46
2014	6.82	6.13	5.79	5.46	5.31	4.76	5.71
2015	7.09	6.47	5.79	5.46	5.31	4.76	5.81
2016	6.68	5.98	5.22	5.59	5.07	4.65	4.53

Table 6: Average crop water requirement of cotton in mm/ LGP from the year 2010 -2016

Year	Avg. ETo mm/day	ETcrop/LGP	WDR (%)
2010	5.81	857.55	12.75
2011	4.62	833.0	26.93
2012	4.56	822.0	52.43
2013	4.46	803.0	-3.86
2014	5.71	842.0	27.43
2015	5.81	857.99	52.29
2016	4.53	816.37	23.84

Results should be the major findings of your experiment. You have to compare the results with previous studies done in same.

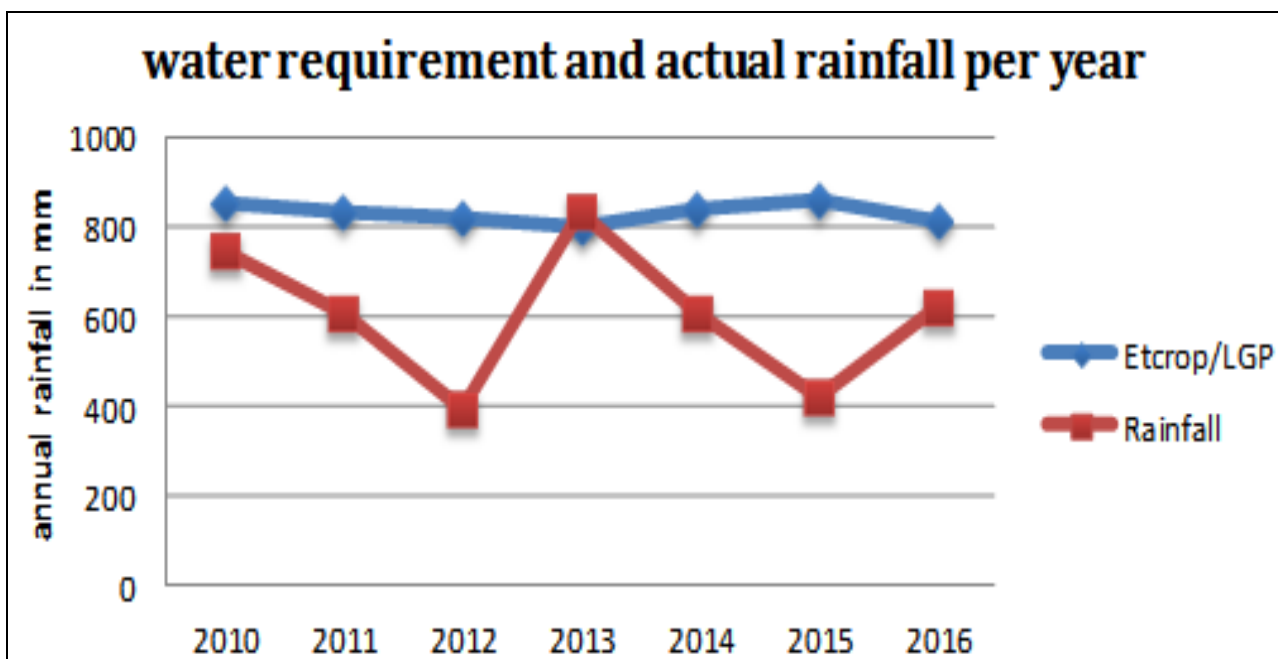


Fig 1: Total annual rainfall per year and calculated ETcrop/LGP

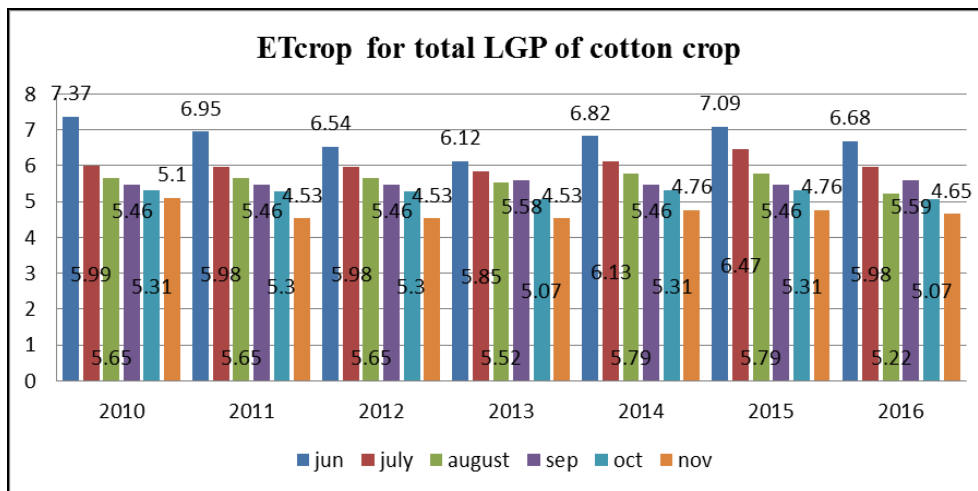


Fig 2: Monthwise Etcrop mm/day for cotton during total LGP in each year from 2010-2016

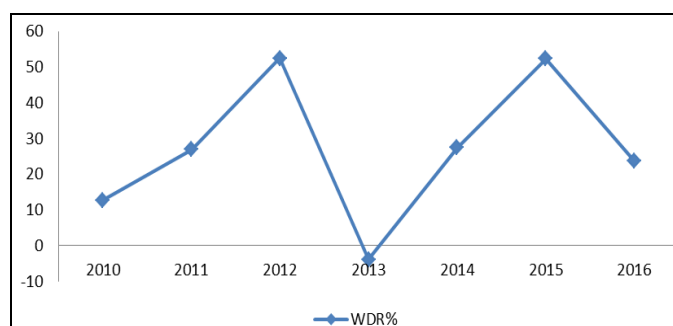


Fig 3: Calculated WDR per year showing irregularity in required rain water availability for cotton growth.

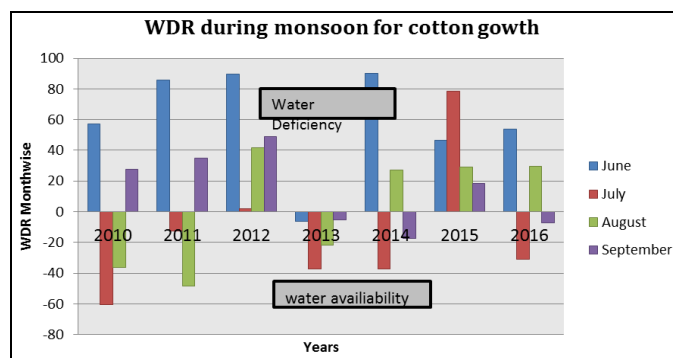


Fig 4: Month wise WDR during 120 days of Monsoon

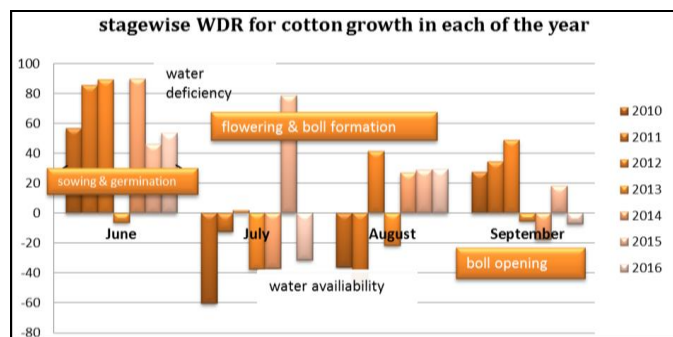


Fig 5: WDR in all the stages of cotton growing period showing water availability is irregular during developmental stage (July- September) and deficiency is continuous from year 2012.

3.1 Discussion

3.1.1 Crop water requirement (ETcrop)

The crop water requirements (table.6) is computed on the basis of BlaneyCriddle method (this method gives results with standard deviation of 6.7%) for total LGP (180 days) of cotton crop which has been scheduled as sowing period from June to whole July followed by developmental stage from early August to late September after that October to November is harvesting periods usually followed by the local farmers of North Maharashtra region for cotton production.

Determination of crop water requirements shown the water need is more than 5mm/day for both sowing and developmental stage in each year, as per the graphical interpretation of graph -2 it has been found that there was high water requirement in sowing period of late June in the range of 6.5 -7.5mm/day, similarly the ETcrop in whole July is also ranges high in between 5.9-6.5 mm/day which is slightly less than late June due to arrival of monsoon and consequently decrease in climatic temperature in each year.

ETcrop for development stage of crop during whole august and September is also ranges high in between 5.5-6.0 mm/day, it is increased more from the year 2014 due to greatly reduced in rainfall below 200 mm which resulting to increase in climatic temperature from the same year.

In the mid-season stage,during late September and whole October the water requirement found in the range of 5.46-5.07 mm/day, when the water deficiency is quite high in each of the year except in 2013, 2014 and 2016.

In the late season stage, in the month of November the matured crop requires less amount of water about 4.6-5.10mm/day where requirement of water fulfilled by the available water bodies like small lakes, rivers, wells etc because of end on monsoon.

3.1.2 Water deficiency ratio (WDR)

As per the study of figure -4 and figure-5 showing monthwise and stagewise WDR during total LGP in each of the year. WDR for each year were calculated by taking the ETcrop / year and for each month were calculated by taking value of ETcrop/ day and subtracting it from the annual /monthly precipitation (without considering the rainfall loss). This has shown that WDR is high at sowing period of late June where

there have been higher requirements of water for the initial stage of crop growth.

Water availability was good in during July in each of the year except in 2015 which was 78.61% dry as compared to other 7 years records. The month of July is considered very important for the flowering.

The last 8 years of rainfall records and Etcrop values has also shown that the cotton crop has been facing water deficiency again in the month of august in each of the year from 2012 of about 41.47% to 29.59% till the current year.

September month of mid-season stage for cotton growth has water deficiency again upto 49.07% till the year of 2012 while there was increase in water availability in 2013 and 2014, while in 2015 again there was deficiency of 18.19%.

For the higher yield of crop cotton need high amount of water in the month of July to September but from study of 8 last year water availibility in the month of august and September is irregular and deficiency seems continuous from the year of 2012.

Except the year 2013 meets the sufficient requirement of water for the crop growth with negative value of -3.86 % WDR.

3.1.3 Irrigation Strategies

On the basis of the study of ETcrop values for a cotton crop has shown that the water requirements is always more than 5mm/day during total LGP. The rainfall records and WDR shown that there was a need to follow proper irrigation designing and scheduling as per the crop requirements. There is also a need to know how much of water is requires to get expected yields of crop to avoid its wastage as water is now has become every precious resource in this semi arid zone due to continuous decline of water table in Jalgaon district. If too much water is applied, yield might even decline as a result of water logging or leaching of nutrients from the root zone 13, 19 (Sun *et al.*, 2006; Cabello *et al.*, 2009) [1, 28, 2, 34]. Considering the soil moisture percentage we can plan irrigation schedule, if suppose plant shows moisture stress at noon, one protective irrigation should be given to crop to avoid moisture stress.

So therefore taking on account the assumptions of FAO, which assumes the 10 mm of rainfall is equal to 10 litres of rain water which has been received by every 10m² of fields. So with rainfall of 1mm every square metre of field receives 1litres of rain water.

On this basis, here we considered the ETcrop mm/day of water as height of rainfall which has been required daily for the crop growth.

Table 7

Year	ETcrop mm/day	Water in litre/m.sq	Water in lit/acre
2010	5.125	5.12	20719.9
2011	4.62	4.62	18696.4
2012	4.56	4.56	18453.68
2013	4.46	4.46	18048.99
2014	5.709	5.709	23103.5
2015	5.813	5.813	23524.39
2016	4.535	4.535	18352.51

There is usually more than 18000 litres per acre of water is

required in each of the year, so this information will be helpful for Maharashtra irrigation department for making availability of sufficient water for irrigation at nearby cotton fields. This information can be also helpful for the farmers who are applying irrigation using drip methods by considering the exact amount of water which is required per acre of cotton field. If insufficient water is applied during the crop growing period, the crop will not develop fully, resulting in low-quality yield or maybe totalloss of yield 14 (Yazar and Sezen, 2006) [3, 29]. On this basis it is said as crop yield and Water productivity (ratio of marketable yield to the volume of water required by the crop) only be increased if a considerable amount of water is added 15 (Geerts *et al.*, 2008b) [4, 30]. In this study areas where water is the most limiting factor, maximizing WP may be economically more profitable for the farmer than maximizing yields (English, 1990) [22, 5]. For instance, water saved by designing proper irrigation schedule and correct water supplements can be used to irrigate more land (on the same farm or water user's community), which will help to compensate the economic loss due to yield reduction (16 Kipkorir *et al.*, 2001; 17 Ali *et al.*, 2007) [6, 31, 7, 32]. Even water transfers from water-rich to water-poor areas are possible, 18 (Hanson *et al.*, 2007) [8, 33].

When rainfall is sufficient and distribution is poor, which we found in the month of July and August in each year, two irrigation at the rate of 4-6 ha cm of water, first at early boll development and second at peak boll development stage is essential. If rainfall is sufficient distribution is proper one irrigation of same amount of water is essential at peak boll development stage. To get a good quality fiber and convenient picking up of fruit, the irrigation should be avoided after boll opening stage.

According to the information of comprehensive district agriculture plan (CDAP) for Jalgaon district which is under cotton cultivation, only 49.1% of area is irrigated. And the two talukas like Bodwad and Muktainagar, having irrigated area 18.6 %and 40.5 % respectively irrigating through wells and ponds which are now under drought condition and in today's condition these areas cultivating cotton without any irrigation facilities due to lack of any sanctioned water project by the government. To provide an irrigation facilities there are 3 major projects in the district out of which Girna and Hatnur are working and irrigating 95047 hac. Regarding small project there are 14 projects out which 9 are completed remaining 5 are near to completion.

4. Summary and Conclusions

Our study has concluded that the farmers should follow the micro irrigation strategies in a proper schedule. Water need of cotton crop is more at the time of sowing where there has been reduction of rainfall consistently from each of the year, and also in the flowering period the rainfall has been reducing every year, therefore effective steps should be taken to overcome from the increasing drought consequent loss in cotton yield.

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