Modelling Irrigation Scenarios for Sprinkler, Drip and Flood Irrigation

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Date: 29th July 2019

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Reference Documents: M&E Framework Document link, Water productivity Note

Following document illustrates the methodology used for modelling drip and sprinkler irrigation scenarios based on collected survey data. This document must be used for computing irrigated AET for varying irrigation methods. It explains the computation process for denominator (AET) in water productivity formula for irrigation methods –

1. Sprinkler
2. Drip
3. Flood

$$water\ productivity = \frac{yield\ (kg)}{Total\ water\ taken\ up\ by\ crop\ (Rainfed\ AET + watering\ AET)(m3)}$$

Where *Irrigated AET = Rainfed AET + watering AET*

Modelling any type of irrigation requires following information on crop, which should be collected irrespective of irrigation method –

1. Crop Name-C01
2. Crop sowing date-C02
3. Crop harvesting date-C03
4. Crop Area in acre-C11
5. Crop damage (to account for / find the cause for less yield – it may be pest attack/animal attack/unable to give water during dry spells/untimely rains)
6. Crop Yield-C15

In addition to this, irrigation information required for different irrigation types, the parameters used while modelling irrigation behaviour and assumptions are explained here

1. Sprinkler Irrigation:

A typical scenario for sprinkler irrigation on field is shown in figure 1.

1. Standard pipes of 20 foot size are connected to form a sprinkler pipeline.
2. The sprinkler nozzles are mounted after each pipe at a spacing of 20 foot on pipeline or at 40 foot spacing after 2 pipes on the pipeline as per the choice of farmer.
3. Normally 10 – 20 sprinkler nozzles are connected on a pipeline based on pump HP (3 HP or 5 HP), nozzle spacing etc.
4. Typically, a sprinkler nozzle has a radius of 20 foot, so that it irrigates in the diameter of 40 foot.

5. The sprinkler pipeline would approximately irrigate a rectangular plot of 40x'y' foot on the field on given day.
6. This sprinkler pipeline with nozzles is moved horizontally across the field to irrigate the entire field.
7. In this way, according to typical farmer practices it takes a few days to irrigate complete field by sprinkler irrigation.

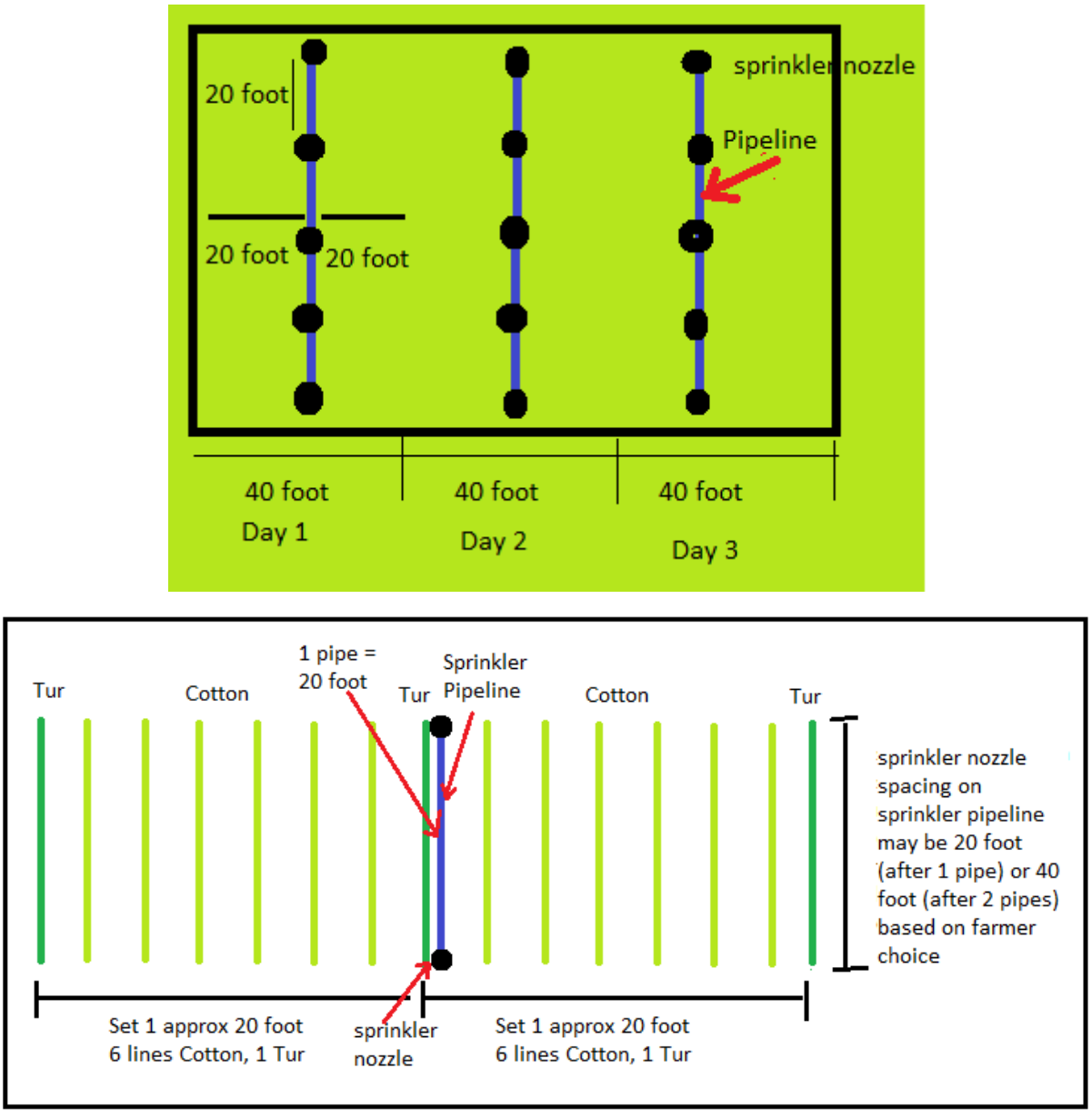

Figure 1 typical sprinkler irrigation on field

8. The choice of sprinkler nozzle spacing is influenced by parameters such as pump HP, water available in well etc.
9. The sowing is done in patterns conforming to wetted area of sprinkler. For example, 6 lines of cotton are followed by one line of tur which form one set of 20 foot on one side of sprinkler pipeline. The sprinkler pipeline is kept between two sets, so that it wets the two sets at a time, after this it is moved by 40 foot to another two sets. In this way it takes more numbers of days to wet an area as it cannot be done all at once like drip.

Assumptions: The norms followed to model sprinkler irrigation are -

1. The sprinkler irrigation water is added to rainfall
2. The crop water requirement has been adjusted for sprinkler irrigation by reducing its crop factor Kc from October onwards to 0.9Kc.
3. If the crop duration is longer than that available in our plugin, then Kc of last crop stage is padded for extra days of crop till its harvest date.
4. The farmer may not know the sprinkler nozzle flow rate, in such case it can be selected from Table 1 below provided by sprinkler manufacturers. This Table 1 contains sprinkler spacing in meter and precipitation rates in mm/hr for each spacing along with its uniformity.

   Selection of sprinkler flow rate:

   i. Sprinkler spacing (in foot) to be converted to meter later – C05 (survey data): Suppose the sprinkler nozzle spacing is (40x40 foot) around 12x12 meter look for this spacing in top row of Table 1. All values under this spacing denote the flow rate in mm/hr. we have selected average or middle value under this spacing 10.2 mm/hr (marked by red circle) here for computation. This method may be used for selection of sprinkler flow rate.

   ii. Since the actual flow rate is influenced by number of factors on field such as pump HP, number of sprinkler nozzles running on the pump which are difficult to account for together, so we select average flow rate based on *sprinkler nozzle spacing*. The choice of spacing 20x20 foot or 20x40 foot depends on factors such as water available in well, how early the farmer wants to irrigate the field and his pump HP.

Table 1 Selection table for sprinkler flow rate in mm/hr

Technical Specifications

Single Nozzle **(Trajectory 25°)**

Precipitation rates (mm/hr) & uniformity (CU) at various spacing

Nozzle	P	Q	D	Spacing (m)							
(mm)	(Kg/cm²)	(lpm)	(m)	12x8	12x9	12x10	12x11	12x12	13x12	18x9	14x12
4.3	2.0	17.23	28	10.8	9.6	8.6	7.8	7.2	6.6	6.4	6.2
	2.5	19.40	28	12.1	10.8	9.7	8.8	8.1	7.5	7.2	6.9
	3.0	21.55	28	13.5	12.0	10.8	9.8	9.0	8.3	8.0	7.7
	3.5	23.31	28	14.6	13.0	11.7	10.6	9.7	9.0	8.6	8.3
	4.0	24.60	28	15.4	13.7	12.3	11.2	10.3	9.5	9.1	8.8
4.7	2.0	20.05	26	12.5	11.1	10.0	9.1	8.4	7.7	7.4	7.2
	2.5	22.21	28	13.9	12.3	11.1	10.1	9.3	8.5	8.2	7.9
	3.0	24.40	28	15.3	13.6	12.2	11.1	10.2	9.4	9.0	8.7
	3.5	26.32	28	16.5	14.6	13.2	12.0	11.0	10.1	9.7	9.4
	4.0	27.12	26	17.0	15.1	13.6	12.3	11.3	10.4	10.0	9.7
5.1	2.0	22.92	28	14.3	12.7	11.5	10.4	9.6	8.8	8.5	8.2
	2.5	24.96	28	15.6	13.9	12.5	11.3	10.4	9.6	9.2	8.9
	3.0	27.71	28	17.3	15.4	13.9	12.6	11.5	10.7	10.3	9.9
	3.5	29.63	28	18.5	16.5	14.8	13.5	12.3	11.4	11.0	10.6
	4.0	31.89	30	19.9	17.7	15.9	14.5	13.3	12.3	11.8	11.4

Note:
- Sprinklers are tested under standard test conditions.
- P= Pressure; Q= Discharge; D = Diameter
- Colour code - Distribution uniformity

CU < 85%	CU - 85-88%	CU - 88-92%	CU > 92%

Source:
https://www.jains.com/PDF/Catalogue_2015/sprinkler/overhead_sprinkler/metal_impact_sprinkler/JI_2_sprinkler.pdf

Such tables will be available for various sprinkler manufacturing companies.

5. The irrigation given is then computed as –

$$Water\ per\ irrigation\ (mm) = Flow\ rate\ in \frac{mm}{hr} * pump\ operation\ time\ per\ day\ in\ hrs$$

Assuming that the entire field was irrigated on single day, this water is added to the rainfall on the date of irrigation as per survey.

Following are 3 examples on computation of irrigated AET from survey. We have selected the red circled flow rates based on our farmer survey. The graphs for each case better explain the modelling methodology.

Relevant questions:

iii. Sprinkler flow rate in LPH – C05
iv. Sprinkler spacing (in foot) to be converted to meter later – C05
v. Number of irrigations given-C06
vi. Watering days per irrigation-C09
vii. Sprinkler operation time on a single area (per day pumping hrs) -C10
viii. Irrigation dates (month-week)– C08

this information is used to run the daily level farm level model.

Table 2 Survey Examples:

Sr. no.	Farmer name	Baban Dane	Gajanan Gaikwad	Gajanan Raut
1	Village	Chapadgaon	Bhidi	Bhidi
2	Taluka	Ghansavangi	Deoli	Deoli
3	District	Jalna	Wardha	Wardha
4	Year	2018	2018	2018
5	Crop Area (Acre)	6	4	6
6	Soil type	clay loam	loamy sand	clay loam
7	Soil depth (m)	1	1	1
8	Sowing date	6th june	10th june	10th june
9	Harvest Date	15th feb	30th November	31st march
10	**Sprinkler spacing (foot)**	**20x40**	**40x40**	**20x40**
11	Sprinkler flow rate (mm/hr)	15	10	15
12	Number of waterings	6	2	5(1st sprinkler,2,3,4 flood)
13	Irrigation time in hrs to irrigate 1 acre* (pumping time per day for given land)	2	6	2.5
14	watering days per irrigation	10 days	4 days	10-12 days
15	irrigation dates (month-week)	31 july, 12th august, 28th august, 9th sept, 18th sept, 28th sept	29th july, 19th september	21st june, 23rd nov, 23rd dec, 23rd jan, 23rd feb
16	**Water per irrigation (mm) = (11*13)** (This should be added to rainfall at every irrigation date (15))	**30 mm**	**60 mm**	**37.5 mm**
17	**Total Irrigation given (mm) = (16*12)**	**180 mm**	**120 mm**	**237.5 (50 mm per flood irrigation)**
18	**Yield (quintal/acre)**	**4.5**	**5.75**	**8.3**

*Irrigation time in hrs to irrigate 1 acre is actually the time required to irrigate each rectangular patch around the sprinkler pipe-line, which is moved throughout the field to irrigate the rectangular patches one after the other.

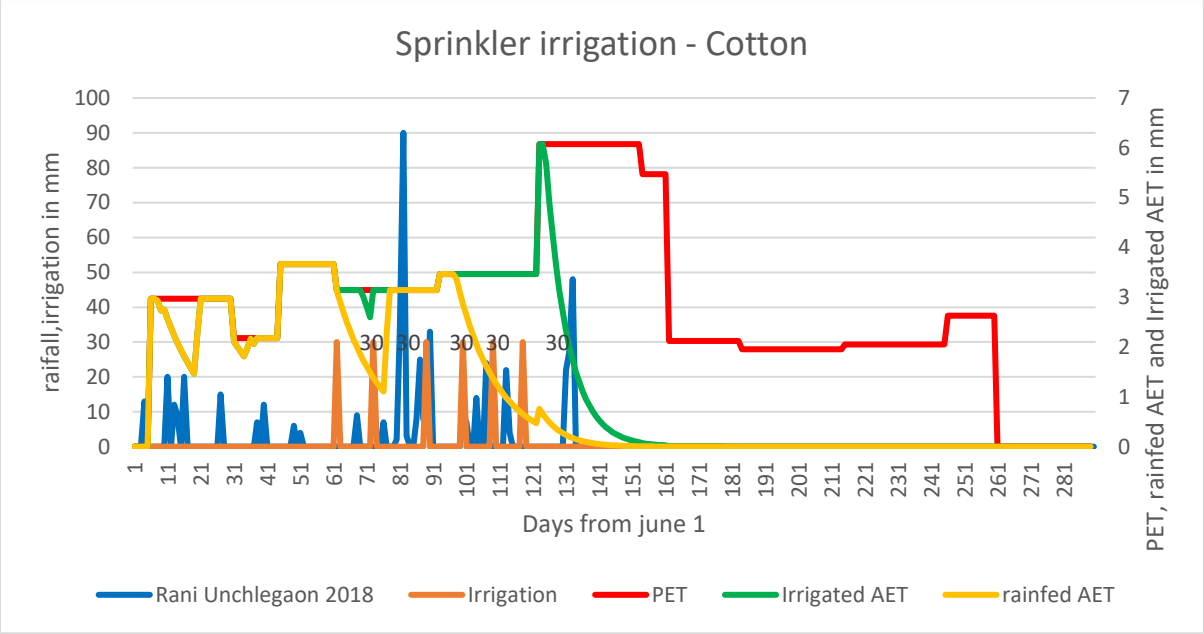

Figure 2 Baban Dane- Chapadgaon, Jalna

Observation: In case of Figure 2, The farmer has given water to crop during dry spell in July and before its flowering stage in august – September. 6 waterings of 30 mm each were given in gap of 10 days, where he took 10 days to water his 6 acre field once by moving the sprinkler pipeline across his field.

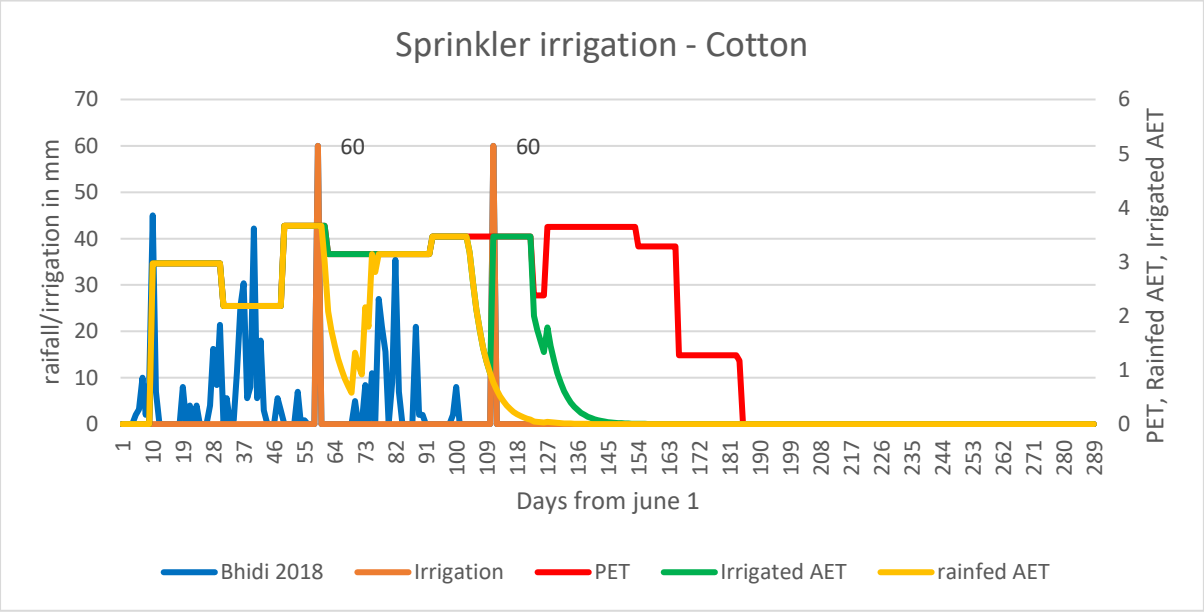

Figure 3 Gajanan Gaikwad Bhidi, Wardha

Observation: Farmer Gajanan Gaikwad in Bhidi village had light deep soil, which he said did not hold much moisture and water penetrated downwards instead of horizontal movement, due to which according to him any amount of irrigation did not suffice his requirement. He operated pump for longer time compared to the other sprinkler farmers as evident through Table 2, and 2 60 mm waterings. He kept cotton crop till December (one flowering of the crop – 2 pickings – around 75% flowering in picking 1 and 25% flowering in picking 2) as his well did not have water after December.

He watered the crop once in July to provide protective irrigation and then in September before flowering, which gave him average yield.

As per his narrative he kept a greater sprinkler spacing of 40x40 foot and was able to water 1 acre in 1 day whereas typically those farmers with sprinkler spacing 20x40 foot took 2 days to water 1 acre.

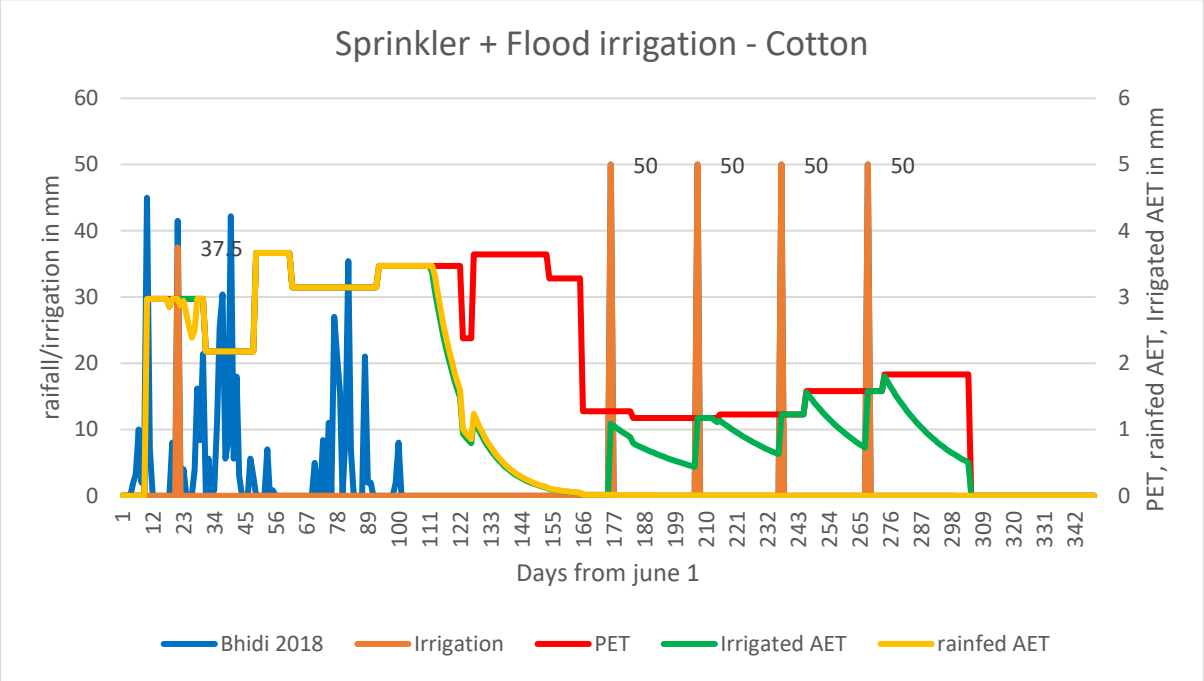

Figure 4 Gajanan Raut Bhidi, Wardha

Observation: Farmer Gajanan Raut applied water to his cotton crop by sprinkler for protective irrigation in early monsoon (37.5 mm), when the crop height was small. He provided flood irrigation (50 mm each) after crop's first flowering, inorder to take second flowering, sprinkler irrigation after the crop flowered would have led to crop damage. With two flowerings his crop was harvested by March end.

This case shows typical farming practice followed based on different stages of crop.

Table 3 Sprinkler Irrigation Water Balance summary

Farmer name	Baban Dane		Gajanan Gaikwad		Gajanan Raut	
Village	Chapadgaon		Bhidi		Bhidi	
Taluka	Ghansawangi		Deoli		Deoli	
District	Jalna		Wardha		Wardha	
Soil Type	clay loam		loamy sand		clay loam	
	Irrigated	rainfed	Irrigated	rainfed	Irrigated	rainfed
Rainfall (input)	577.0	397.0	610.8	490.8	728.3	490.8
Runoff	167.4	102.2	57.9	40.8	217.6	125.9
Infiltration	409.6	294.8	552.9	450.0	510.7	364.9
SM	0.0	0.0	6.0	6.0	25.6	8.3
GW recharge	0.0	0.0	191.4	166.8	4.0	0.0
AET	409.6	294.8	355.5	277.2	481.0	356.6
PET (input)	811.0	811.0	522.2	522.2	696.6	696.6

Deficit	401.4	516.3	166.7	245.0	215.6	340.0
Irrigation	180		120		237.5	

* All values are in mm

Inference:

1. From Rainfed and Irrigated water balance in Table 3 for sprinkler irrigation, it becomes clear that the water amount given through irrigation does not become entirely available to the crop as AET, but gets divided among other water balance components such as ground water soil moisture based on soil properties.
2. Also, the choice of irrigation method is influenced by multiple factors like water availability, finance availability for purchase of micro irrigation equipment, crop and *growth stage of crop* to name a few.
3. These minute details such as number of flowerings, pickings, other external factors affecting yield and watering should get properly captured in survey, so that water productivity may be measure accurately.
4. The effect of providing protective irrigation and irrigation before flowering in can be seen to translate into yield increase.
5. This irrigated AET in mm can be converted to meter-cube by multiplying with crop area to get the denominator in water productivity formula 'Total water taken up by the crop'.

$$water\ productivity = \frac{yield\ (kg)}{Total\ water\ taken\ up\ by\ crop\ (Rainfall\ AET + watering\ AET)(m3)}$$

$$\boldsymbol{Total\ water\ taken\ up\ by\ the\ crop\ (m3) = Total\ crop\ area\ in\ acre * Irrigated\ AET\ (mm) * 4}$$

2. Drip Irrigation

Assumptions:

1. The drip irrigation water is added to soil moisture with 90% efficiency
2. Similar to sprinkler, The crop water requirement has been adjusted for drip irrigation by reducing its crop factor Kc from October onwards to 0.6Kc.
3. The farmer usually knows the dripper/emitter flow rate and *can tell how much water is thrown out by emitter in an hour (LPH).* This is used to compute the water per irrigation to be used in model.
4. The irrigation per day is computed as –

    a. Number of drippers in crop area = crop area in acre*4046 (sq-m)/ dripper spacing (sq-m)
    b. $Irrigation\ water\ in \frac{mm}{day} = \frac{[number\ of\ drippers\ in\ crop\ area * dripper\ flow\ rate\ in\ LPH * pumping\ hrs\ per\ irrigation]}{crop\ area\ in\ acre * 4046}$
    c. This irrigation water is added to the model on the irrigation dates (for number of days in each irrigation) obtained from farmer survey

5. If the crop duration is longer than that available in our plugin, then Kc of last crop stage is padded for extra days of crop till its harvest date.

Relevant questions:

1. Dripper flow rate in LPH – C05
2. Dripper spacing (in foot) to be converted to meter later – B13
3. Number of irrigations given-C06
4. Watering days per irrigation-C09
5. Dripper operation time (per day pumping hrs) -C10
6. Irrigation dates (month-week)– C08

this information is used to run the daily level farm level model.

Table 4 Drip Irrigation Farmer Samples

Sr. no.	Farmer name	Yashodabai	Kasubai Jadhav	Vitthal Munchal
1	Village	Chapadgaon	Tongaon	Tongaon
2	Taluka	Ghansawangi	Aurangabad	Aurangabad
3	District	Jalna	Aurangabad	Aurangabad
4	Year	2017	2018	2018
5	Crop Area (Acre)	10	2	1.5
6	Soil type	clayey	gravelly sandy clay loam	gravelly sandy clay loam
7	Soil depth (m)	1	1.2	1
8	Sowing date	6th june	6th June	8th june
9	Harvest Date	15th feb	15th dec	20nd December
10	Dripper spacing (sq-m)	0.45x1.2	0.5x1.6	0.3x1.3
11	Number of drippers = (5) * 4046/ (10)	74925	10115	15561
12	Dripper flow rate (LPH)	8	6	6
13	Number of waterings	6	5	10
14	Irrigation time (hrs/day)	1.5	3	2.5
15	watering gap between irrigations (days)	10 days	10 days	7 days
16	irrigation dates (month-week)	starting from 13th Nov to 22nd Dec	starting from 1st august to 16th september	starting from 1st august to 13th october
17	Irrigation water (mm/day) = [(11) * (12)*(14)] / [(5) *4046]	22.22	22.50	15.38
18	Total irrigation (mm) = (17)*(13)	133	112.5	153.8

19	Total Effective Irrigation (90% efficiency)	120	101	138
20	Yield (quintal/acre)	3.5	4	10

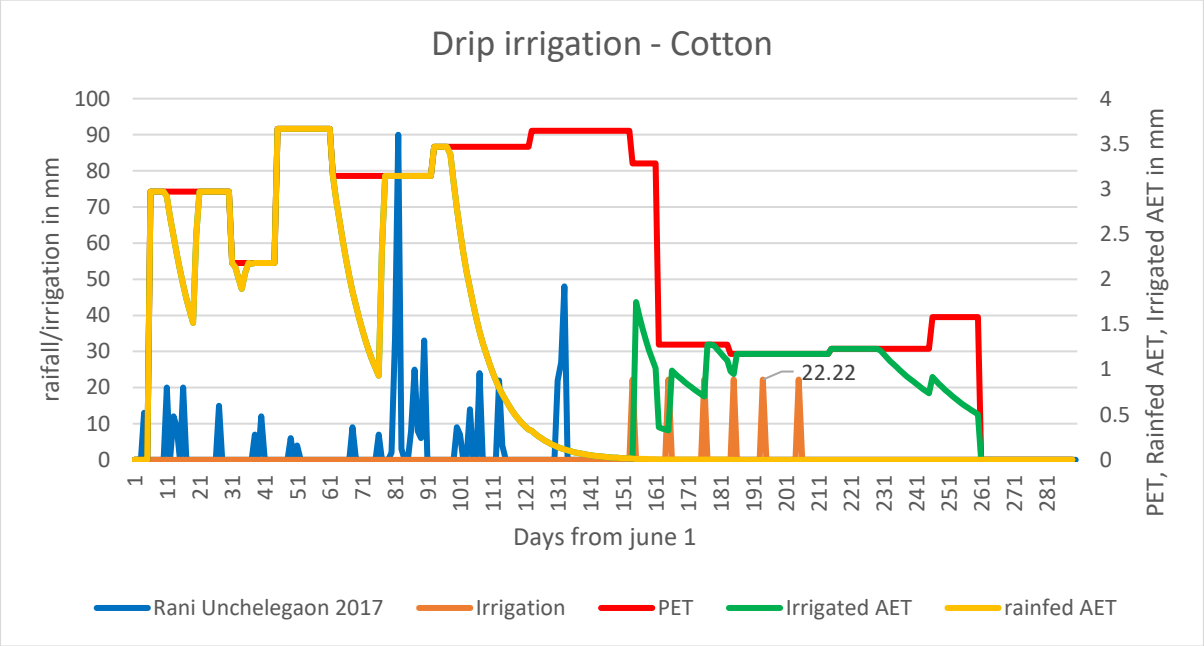

Figure 5 Yashodabai Chapadgaon

Observations: In case of Figure 5, Farmer Yashodabai has irrigated her crop starting from November onwards. This is because her well did not have water earlier. She was not able to provide for protective irrigation during dry spells which affected her yield (3.5 quintal/acre). She took second flowering by providing water in November and December, when she had water in well due to nearby canal rotation.

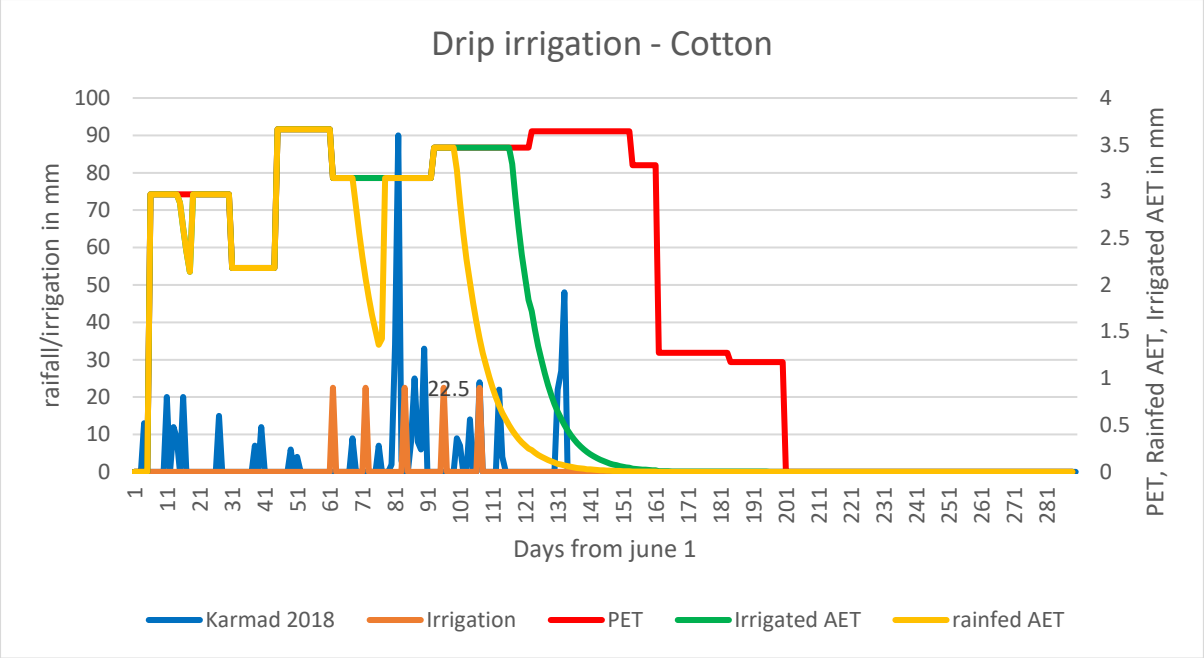

Figure 6 Kasubai Jadhav Tongaon

Observations: In case of Farmer Kasubai, 5 waterings were given to cotton before the flowering stage in gap of 10 days. Crop was harvested in December after one flowering with a yield of 4 quintal per acre.

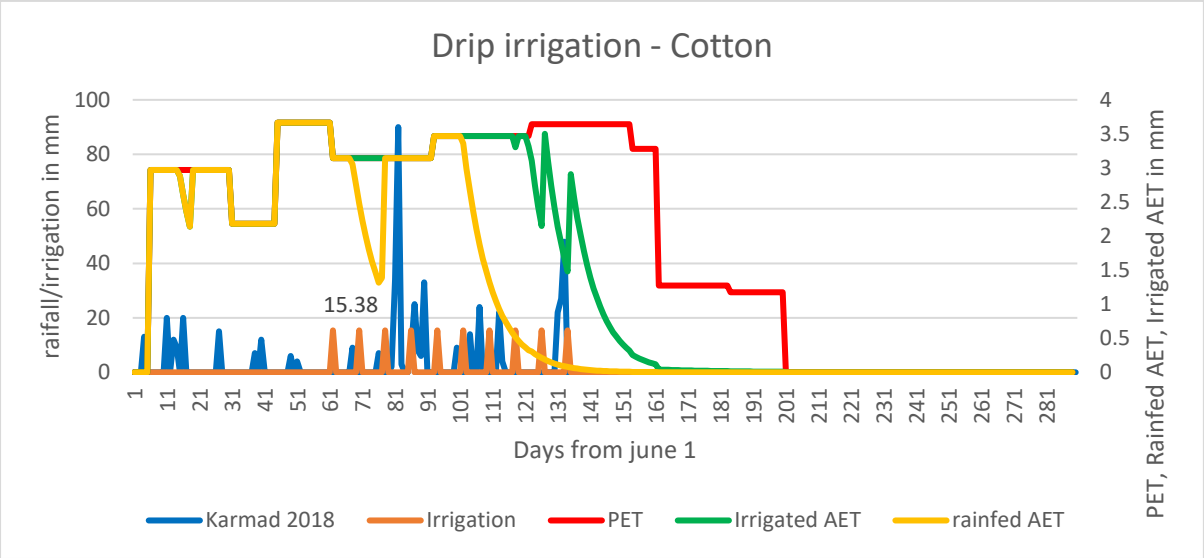

Figure 7 Vitthal Munchal-Tongaon

Observations: Farmer Vitthal Munchal gave 10 waterings to cotton before and during its flowering stage from August to October and obtained a good yield of 10 quintal per acre through one flowering. He harvested the crop by mid December.

Table 5 Drip Irrigation Water Balance Summary

Farmer name	Yashodabai Sarpanch		Kasubai Jadhav		Vitthal Munchal	
Village	Chapadgaon		Tongaon		Tongaon	
Taluka	Ghansawangi		Aurangabad		Aurangabad	
District	Jalna		Aurangabad		Aurangabad	
	Irrigated	rainfed	Irrigated	rainfed	Irrigated	rainfed
Rainfall (input)	397.0	397.0	475.0	475.0	475.0	475.0
Runoff	107.2	107.2	152.2	132.6	145.0	130.4
Infiltration	289.8	289.8	322.8	342.4	330.0	344.6
SM	11.6	0.0	30.1	30.0	10.2	10.0
GW recharge	0.0	0.0	18.2	6.8	37.5	21.5
AET	398.3	289.8	375.8	305.6	420.7	313.1
PET (input)	634.1	634.1	555.8	555.8	555.8	555.8
Deficit	235.8	344.2	180.0	250.2	135.1	242.8
Total Irrigation	133.3		112.5		153.8	
Total Effective Irrigation (90% efficiency)	120		101.0		138.0	

Inference:

1. In case of drip irrigation it can be noted that watering can be done during any growth stage of the crop, unlike sprinkler. Also drip has less maintenance compared to sprinkler as it has to be installed once in the field during sowing, whereas sprinkler pipeline needs to be moved to cover entire field.
2. Around 100 – 200 mm of watering is given to crops through drip/ sprinkler irrigation
3. This irrigated AET in mm can be converted to meter-cube by multiplying with crop area to get the denominator in water productivity formula 'Total water taken up by the crop'.

$$water\ productivity = \frac{yield\ (kg)}{Total\ water\ taken\ up\ by\ crop\ (Rainfall\ AET + watering\ AET)(m3)}$$

$$\boldsymbol{Total\ water\ taken\ up\ by\ the\ crop\ (m3) = Total\ crop\ area\ in\ acre * Irrigated\ AET\ (mm) * 4}$$

3. Flood Irrigation:

In case of flood Irrigation, we have assumed 50 mm watering per irrigation and added it to rainfall in the model as per irrigation dates obtained in survey. Figure 3 can be referred for this where last 4 irrigations have been added as 50 mm flood type.

It must be noted here that AET will usually be less than the water applied in all irrigation cases and will depend on soil parameters.