Design and Planning of Overhead Irrigation System for Ground Water Sharing

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Abstract

Overhead irrigation system is an optimal way of using water to protect *kharif* crops in semi-arid regions. The study aims at modification in system design, preparation of optimal operational plans in terms of equity and assessment of irrigation system designs. The major findings in the sites are to fix the overhead sprinklers at a spacing to attain 30 or 50 percent overlapping of wetting zone. Second, instead of giving one or two critical irrigations, it is possible to provide recommended irrigation schedules even in Non borewell growers (NBWG) land by adopting crop wise operating schedules for the three groups with the available water. Sprinkler heads which are presently used can meet the crop water requirement (CWR) of groundnut within, 16 to 18 min during *kharif* and *rabi* seasons respectively. Total number of irrigations required for groundnut during *kharif* and *rabi* are 10 and 12 respectively with an irrigation frequency of 11 days (without considering rainfall). Following the recommended schedules Mahabubsubhani group can irrigate 14.7 ha/day whereas, Eedulavanka group and T-Kothapally group can irrigate to 6.26 ha/day and 4.7 ha/day respectively.

Key words: Community sprinkler irrigation designs, Operating schedules, Optimal operational plans

Declining groundwater levels are very common in India especially under dryland conditions. So, farmer has to adopt advanced technology which is accessible such as pressurized irrigation system, porous pipe irrigation, precision farming etc. for conserving water and to increase the efficiency. The term efficiency technically means adopting proper scheduling at field level [1]. The prime objective of applying water to the plant is according to its requirement which are determined by soil, environment conditions and many other factors. Though agriculture remains the most important economic activity of rural India, most of the farmers are leaving the lands barren due to lack of water for irrigation due to failure of bore wells. The institutional approach is to manage groundwater by arresting over-exploitation of groundwater and for mitigating environmental consequences through establishment of a regulatory framework. Towards this end the Government of Andhra Pradesh introduced the Andhra Pradesh Drought Adaptation Initiative (AP DAI) implemented in Ananthapur district. The project aims to protect *kharif* crops during prolonged dry spell by pooling the bore wells to share water among Bore Well Growers (BWG) and Non-Bore Well Growers (NBWG) by forming a community-based irrigation system.

Despite the fact that Ananthapur district falls under rain shadow region, agriculture remains the important source for economic activity [2]. Due to irregular and improper distribution of rainfall, irrigation is necessary to protect the rainfed crop. Micro irrigation is a good alternative for the arid and semiarid regions as it is the modern irrigation technology suitable for almost all crops and climatic conditions. The focus of the study is to analyze the designs of CBSIS and develop recommendations to improve the system performance and efficiency with the available resources and preparation of optimal operational plan for the group of pooled growers. The designs of semi-permanent sprinkler irrigation system (SPSIS) have been prepared for the three groups located in three different mandals (cluster of villages) of Ananthapur district. Assessment of optimal operational schedules, by using the crop water requirement and available water plays the key role for the success of community-based sprinkler irrigation system. Randomly 3 groups were selected out of 14 in the district and suitable SPSIS designs and operational schedules were prepared for the available resources.

MATERIALS AND METHODS

The selected sites were surveyed and plotted using Auto CAD 2007. Each of the farmers from the three groups was interviewed personally to find the prevailing site conditions and operation methods and strategies followed.

Study area

Ananthapur district is the southern part of Andhra Pradesh and located in rain shadow region. Available water in the study area and the site conditions are detailed in the (Table 1). Three groups from three different mandals located in Ananthapur district are Yarraguntla village of Garladinne mandal, T kothapally village of Gooty mandal and Eedulavanka village of Nallamada mandals.

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Out of 553mm of normal rainfall in Ananthapur district, 330 mm received during south west monsoon i.e. during *kharif* season. The soils of these regions are mostly red soils. The texture is loam to sandy loam. This is mostly suited to irrigated and dry land crops. The average depth of soils is 180 cm in while the depth of top layer is nearly 40-50 cm, covering one third of the soil depth [2].

Table 1 Details of the resources available at sites

Group name	BWG		NBWG		No. of bore wells	Available water (6h of pumping), m³ / day	Total area (ha)
	No. of farmers	Area (ha)	No. of farmers	Area (ha)			
Mahabubsubhani	4	4.86	21	32.89	7	724	37.75
Eedulavanka	7	8.91	12	8.91	7	621.86	17.82
Mamidimandla	4	2.43	13	7.29	4	195	9.72

Water available: Availability of water is measured during summer season by collecting the water in a container of known capacity and the time required to fill is noted. The pump has been operated for 6 hours to know whether there is any variation or decrease in discharge if the pump is operated continuously. After finding the safe discharges of the bore well, the irrigation system has been designed for the safe discharge.

Assessment of suitability of the irrigation system

Farmers who are getting water from the bore well farmers to meet the critical irrigation for protecting the rainfed crops (*kharif* crop) needs to utilize the water efficiently. It is already proven that the field application efficiency is highest for drip irrigation followed by sprinkler irrigation, furrow and then border irrigation [3].

In order to meet the irrigation requirement of the crops with the available water sources, fund available and government policies, sprinkler irrigation system was selected in all the three mandals. The factors considered to evaluate the design are net depth of water application, irrigation frequency, operating hours and operating schedules. Operating pressure required for sprinkler irrigation intended for uniform drop let size and wetting pattern is 2.5 kg/m².

Net depth of water application (Dnet)

The depth of water application is the quantity of water, which should be applied during irrigation to meet the crop evapo-transpiration. The computation of the net depth of water application is calculated using the formula:

$$D_{net} = (FC - PWP)x(P)x(RZD)$$

Where, Dnet is net depth of water application per irrigation for the selected crop (mm), FC is soil moisture at field capacity (mm/m), PWP is soil moisture at the permanent wilting point (mm/m), RZD is the depth of soil that the roots exploit effectively (m), P is the allowable portion of available moisture permitted for depletion by the crop before the next irrigation (generally considered as 50% depletion).

Available soil moisture: The difference between field capacity and permanent wilting point will give the available soil moisture (water holding capacity), which is the total amount of water that the crop can use depending on the crop sensitivity to stress. Available soil moisture for sandy loam ranges from 90-150 mm/m. Depth of root zone considered groundnut is 0.5-1.00 m, pigeon pea is 0.7-1.5 m, maize is 1.0-1.7 m and tomato is 0.5-0.6 m [4]. Therefore, the average value is considered for calculating the depth of irrigation.

Irrigation frequency: Irrigation frequency is the time it takes the crop to deplete the soil moisture at a given soil moisture depletion level. After establishing the net depth of water application, the irrigation frequency at peak water demand can be determined using the following equation

$$Irrigation\ frequency(IF) = \frac{D_{net}}{WU}$$

Where, IF irrigation frequency (days), Dnet is net depth of water application (mm), WU is peak daily water use (mm/day). *Operating Hours***:** Operating hours is the time to which each section or the sprinkler set has to be operated to meet the irrigation requirement:

$$Operating\ Hours = \frac{PWR}{AR}$$

Where, PWR is peak water requirement (l/m²/day), AR is application Rate (l/hr/m²)

AR (*Application rate*): The rate at which water is applied to a particular area.

$$= \frac{AR\ Discharge\ of\ the\ sprinkler(lph)}{Distance\ between\ lateral(m)\ x\ Distance\ between\ the\ sprinklers(m)}$$

Number of rotations in a day: It depends on the available water; no. of sprinkler sets and discharge of each sprinkler set.

$$Rotations\ per\ Day = \frac{Q}{(Discharge\ of\ sprinkler\ set)\ x\ (No.of\ sets)}$$

Where, Q is total discharge of the bore wells (lph) and discharge of the sprinkler set (lph)

The management practices followed by the beneficiaries in CBSI adapted areas and the type of the crops grown are of paramount importance to the water resource utilization pattern and its development. These factors are ultimately reflected in terms of increased cultivated area and crop production. So, their assessment is necessary.

RESULTS AND DISCUSSION

Net depth of water application and irrigation frequency

Net depth of water application and irrigation frequency for the major crops, in red soil considering the 150 mm/m of available soil moisture has been assessed. Net depth of water application for ground nut is 75mm with 1m of root zone depth, similarly for pigeon pea it is 112.5 mm for 1.5 m, maize it is 127.5 mm for 1.7 m and tomato with 0.6 m of root zone depth is 45 mm net depth of water application. Irrigation frequency was obtained for four major crops during *kharif* and *rabi*. Groundnut requires 10 irrigations during *kharif* and 11 during *rabi* with an irrigation interval of 11 and 10 days respectively (without considering the rainfall) for 110 days of the crop growing period. Similarly for pigeon pea with 170 days of growing period requires 10 irrigations with 17 days of irrigation interval, maize when considered for 120 days requires 6 and 5 irrigations with an interval of 18 and 22 days during *kharif* and

rabi respectively. Tomato with 145 days of crop period requires 24 irrigations with 6 days of interval during *kharif* and *rabi*.

Estimation of operating schedules for CBSIS

Prevailing operating schedules

Interaction with the farmers revealed that bore well farmers are irrigating the field everyday by leaving each set to operate for 3 hrs and then shifting to second patch operating again for 3 hrs resulting in over irrigation. In turn, this is leading to deep percolation of water below the root zone, leaching of micronutrients and wastage of pumped water and erosion of soil. Spacing between sprinkler to sprinkler and lateral to lateral is 12 m which is being maintained in all the fields without overlapping [5-6]. NBWG are getting only the critical irrigation once or twice during the crop period. Modifications can be adopted and can be admitted by all the members of the group are detailed further.

Site wise recommended operating schedules

Yerraguntla, Mahabubsubhani group: With the available resources to achieve maximum yields operational schedules are planned according to the available water by dividing the total group into 5 to 6 sub divisions and can be irrigated in 5 to 6 days. With the available water each group of 9.43 ha could be irrigated every day by operating each set for 16.24 min to meet the water requirement (WR) for groundnut. But to irrigate 9.43 ha per day, this group may require 4 additional sprinkler sets. So, alternative operation schedule is planned according to the available water and number of sprinkler sets with the group. Considering 6 h of power per day and with the available sets of sprinkler units, 8.05 ha and 6.81 ha can be irrigated per day during *kharif* and *rabi* seasons respectively, by considering 30 min for each operation along with grace period for shifting the unit. Without considering the precipitation during *kharif* entire area of the group can be irrigated in 5 days however during rainy season few irrigations can be skipped according to precipitation [7-9].

Dunnikota, Eedulavanka group: Though the number of subdivisions required is two during *kharif* and during *rabi* as per the available water. But this group is having only 8 sprinkler sets, so, scheme of operation has been planned to suit that. Following the same procedure, the land holding of 17.81 ha of this group can be irrigated by sub dividing into 5 sections and each in a day. Time of operation for each section is considered for 30 min, providing some grace period for shifting. Maximum 3.64 ha can be irrigated in a section per one day [10].

Tkothapally, Gangireddy group: This group has a holding of 9.71 ha and 6 sprinkler sets with an available water 194 m^3/day. Accordingly maximum 2.98 ha can be irrigated per day. The total WR of the group can be met within 4 days.

Design of community based micro irrigation system

The design adapted in the field was assessed in a view to check the feasibility to improve with the present available resources. For all the groups, sprinkler system has been sanctioned and the technical norms were as per the guiding principles of Andhra Pradesh micro–Irrigation Project (APMIP). The sprinkler set sanctioned was of 5 lengths of 75 mm HDPE pipe (each 6m length), 5 sprinkler nozzles with discharge the 0.5 l/s and with radius of throw 6 m, raiser pipes and fittings. No. of sets sanctioned were based on the availability of fund as per the budget allotment to the group, size of group and no of farmers participating [11].

Before starting sprinkler irrigation design, the basic considerations were application rate and the spacing of the sprinklers. The application rate should be such that there should not be any runoff or stagnant water patches on the surface, the sprinkler application rate should not exceed the basic soil infiltration rate. The sprinklers has to be placed in such a way that there won't be any dry patches in between. The optimum spacing for the nozzle size selected was 8.4 m × 8.4 m with 30% overlapping (Fig 1) and the ideal spacing would be with 50% overlapping. It is known that micro irrigation is the application of precise amount of water for a long duration. The efficiency of water can be improved by selecting a sprinkler head that discharges water which suits infiltration rate of the soil and it also arrests the soil erosion problem [12].

Assessment of sprinkler irrigation system design

Designs of CBMIS of three groups suitable with the available resources are detailed below:

Yerraguntla, Mahabubsubhani group CBMIS

In this group, out of 25 farmers, four farmers own seven bore wells, and sharing water among non-borewell growers to meet critical irrigation during *kharif* season. The major crop grown during *kharif* and *rabi* is groundnut. The borewell discharges were measured during summer and considered in assessing the available water.

Site condition: Four borewells are located outside the field which is 2500 m away from the CBMIS group. Pipe line is already existing which is connecting the rest of the three borewells as they belong to the same family. The maximum pipe size that is available under APMIP is 110 mm that has been laid to pool all the seven borewells. The layout of the site is shown in (Fig 2).

Twenty percent of actual discharge measured at the BW points is deducted to consider the head loss in pipe line during conveyance. System was designed to meet the irrigation requirement with the available (existing) sizes of conveyance system. This group has 18 sets of sprinkler units. The available area which can be irrigated is assessed considering the PWR of groundnut. Actually, the system is designed to irrigate BWG field and share water to NBWG only to save the crop during prolonged dry span during *kharif* season. But it is observed that borewells are being operated daily to irrigate the BWG field which is only 4.86 ha. Whereas water required to irrigate 4.86 ha is 335 m^3 and total water required during the crop period is 3686 m^3 (3 months). So, instead of only critical irrigation the rest of the water which is being pumped every day can be shared among the NBWG farmers so that their crop yields can be improved in an area of 32.89 ha, which is connected with the borewell system [13].

To meet the irrigation requirement of total field (37.75 ha), irrigation system can be planned in such a way that without over irrigating the patch and leaving the sprinkler set ideal while shifting the unit to other patch. Entire 18 sets have to be used as single unit according to the pressure availability instead of using single set by one farmer. Proposed design shows the area can be irrigated using 2 sprinkler sets with 30% overlapping and providing optimal irrigation as per PWR of particular crop. Therefore, with the available water (pumped for 6 h/day), total area can be irrigated within 4 days. Crop wise WR and design data are shown in (Table 2-Table 3) respectively. Irrigation requirement can be met by planning an irrigation system with PWR of each crop. APMIP has formulated standard PWR of most of the crops which are considered for designing the irrigation systems for different crops in Andhra Pradesh. The

planning of irrigation system for the major crops grown in Ananthapur region like groundnut, pigeon pea, maize and tomato during *karif* and *rabi* seasons with the available water.

With the net depth of irrigation and PWR of particular crop, irrigation frequency has been determined and operating schedules are recommended [14].

Table 2 Water requirement (mm/day) for *kharif* and *rabi* crops for Yerraguntal - Mahabobsubhani group

Parameters	Groundnut (K)	Pigeon pea (K)	Maize (K)	Tomato (K)	Groundnut (R)	Maize (R)	Tomato (R)
Peak Water requirement, mm/day	6.90	6.67	6.90	7.20	7.87	5.89	7.35
Water required, m³/ha	69.00	66.70	69.00	72.00	78.70	58.90	73.50
Net depth of irrigation, mm	75	112.5	127.5	45	75	127.5	45
Irrigation Frequency, days	11	17	18	6	10	22	6
Number of irrigations required	10	10	6	23	12	6	24
Total water requirement for 32.89 ha, m³	2269	2194	2269	2368	2588	1937	2417
Water requirement for 4.86 ha, m³	335	324	335	350	382	286	357
Water requirement for 37.75 ha, m³	2437	2356	2437	2543	2780	2080	2596
Number of sections	3	3	3	3	4	3	3

Table 3 Design data of Mahabubsubhani, Eedulavanka and Tkothapally groups

Details	Group name		
	Mahabubsubhani	Eedulavanka	Tkothapally
Number of borewells	7.00	7.00	4.00
Pumping capacity of the bore wells per day, m³/6h	1313.50	1731.38	---
Actual total available water in the block, m³/day	724.00	621.86	195.00
Total head loss in conveyance	21.00	21.00	15.00
Topography, m	5.00	1.50	4.50
Required operating pressure for sprinkler system, m	25.00	25.00	25.00
Dicharge of sprinkler, lps	0.50	0.50	0.50
Dicharge of sprinkler set, lps	2.50	2.50	2.50
Crop water requirement (groundnut), mm/day	6.90	6.90	6.90
Crop water requirement (groundnut), m³/day/ha	69.00	69.00	69.00
Area can be irrigated with the available water per day, ha	10.49	9.01	2.83
Area of bore well Growers (BWG), ha	4.86	8.91	2.43
Total water required to irrigate BWG field, m³	335.22	614.79	167.61
Area of non-bore well Growers (NBWG), ha	32.89	8.91	7.29
Total water required to irrigate NBWG field, m³	2269.74	614.79	502.83
Spacing between sprinklers, m	8.40	8.40	8.40
Spacing between lateral, m	8.40	8.40	8.40
Application rate, mm/h	25.50	25.50	25.50
Operating time of each section, min	16.23	16.23	16.23
Net depth of irrigation for groundnut, mm	75.00	75.00	75.00
Irrigation frequency	11.00	11.00	11.00
Power available per day, h	7.00	7.00	7.00
Number of rotations in 6 h	22.18	22.00	22.00
Number of sprinkler sets available with the block	18.00	8.00	6.00
Discharge required to operate each set, m³/h	9.00	9.00	9.00
Discharge required to operate 2 sets, m³/h	18.00	18.00	18.00
Carrying capacity of 75 mm pipe, m³/h	18.00	18.00	18.00
Area can be irrigated as one section, ac (2 sprinkler sets)	0.07	0.07	0.07
Main line of 90 mm diameter can carry water, m³/h	40.00	36.00	36.00
Area can be irrigated at a time, ha	0.16	0.14	0.14
Total area can be irrigated with available water per day, ha	10.49	9.01	2.83

Dunnikota, Eedulavanka Group CBSIS:

In Eedulavanka group, 19 farmers have entered in to an agreement in which 7 are BWG having 8.9 ha of land and the remaining 8.9 ha is of 12 NBWG. The drawing of design is shown in (Fig 3). With the available resources at Eedulavanka, the water requirement for different crops during *kharif*, *rabi* and for total group area, (BWG site and NBWG site). Available water per day is 621 m³/day, the required water for 8.9 ha land is nearly equal to available water during *kharif* and *rabi*. Also, during the crop period, the number of irrigations required is 10. Therefore, for BWG and NBWG, only 20 days the water has to be pumped during the crop period (except for tomato). For

growing tomato, the total water requirement for 8.9 ha of land is 641 mm and 654 mm during *kharif* and *rabi* and has to be given in 23 irrigations. So, during the crop period of 145 days, total irrigations required is 46 to meet the irrigation requirement of 17.81 ha.

Therefore, according to the availability of water during *kharif* and *rabi*, crops can be planned, crop wise water requirement is shown in (Table 4). If the discharges of the BW still decrease, farmers in the group can plan for tomato as the total water required needs to be distributed in 23 irrigations during 145 days of crop period allowing bore well to recharge and attain the static water level [15-16].

Table 4 Water requirement (mm/day) for *kharif* and *rabi* crops for Eedulavanka group

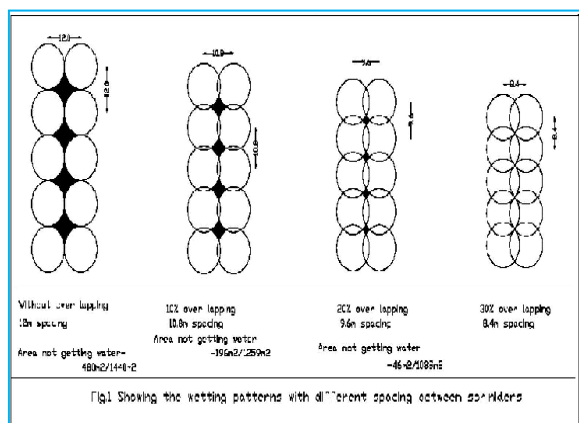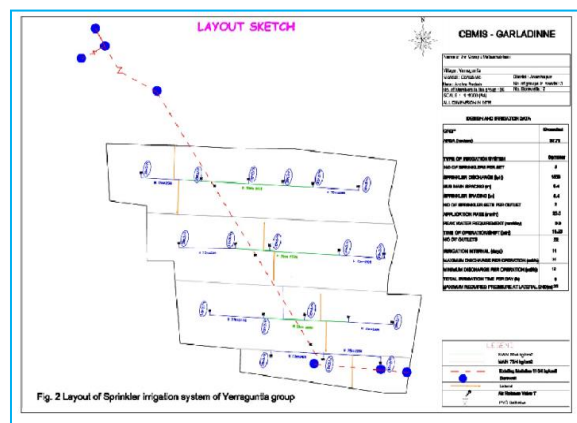| Parameters	Groundnut (*Kh*)	Pigeon pea (*Kh*)	Maize (*Kh*)	Tomato (*Kh*)	Groundnut (*R*)	Maize (*R*)	Tomato (*R*)
Water required m^3/ha	69	67	69	72	79	59	74
Irrigation frequency, days	11	17	18	6	10	22	6
Number of irrigations required	10	10	6	23	12	6	24
Total water requirement for 17.81ha, m^3	1229	1188	1229	1282	1402	1049	1309
Total water requirement for 8.91ha, m^3	615	594	615	642	1731	1296	1617
Total water requirement for 8.91ha, m^3	615	594	615	642	1731	1296	1617
Number of Sections	2	2	2	2	2	2	3

Fig 1 Showing the wetting pattern
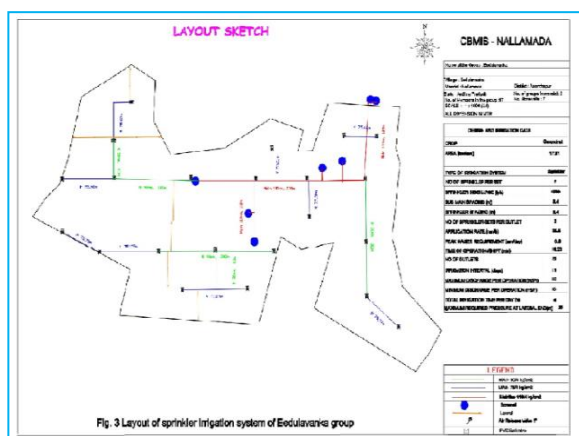

Fig 2 Showing the layout sketch of Yerraguntla
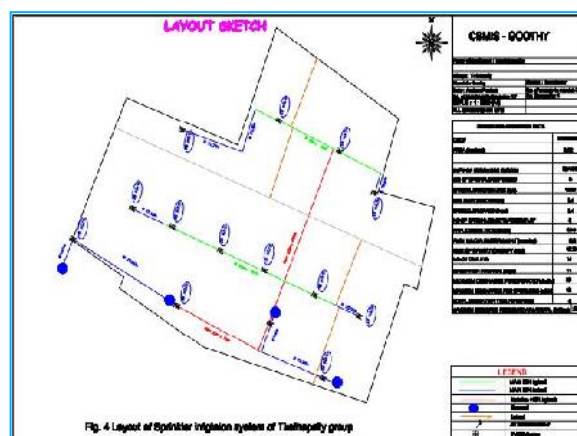

Fig 3 Showing the layout of Eedulavanka group

Fig 4 Showing the layout of Tkothapally group

Tkothapally, Gangireddy Group CBMIS

The total water available in this group from four borewells is 195 m^3/day, with a land holding 2.43 ha. The BWG land can be irrigated within one day out of 10 days of irrigation interval and the rest of the area which is of NBWG i.e. 7.29 ha can be irrigated in 3 days. The group is having six sprinkler sets from which, two sprinklers sets are operated as a unit and there are 3 units operated for 6 h/day. Total 2.97 ha can be irrigated, but every time while shifting the sprinkler sets time will be wasted since the power is available only for 7 h. So, the effective time of irrigation will be decreased due to waste of time in shifting the unit. The alternative is to increase the sprinkler units or to irrigate the group by sub-dividing it into 0.07 ha patches and follow the sequence to complete one cycle within 10 days of irrigation frequency. BWG can irrigate their lands in one when compared to available water, therefore crop diversification and water sharing is possible (BWG land and NBWG land) during *kharif* and *rabi.* Design data is shown in (Table 5) and layout of the field is shown in (Fig 4).

Table 5 Water requirement (mm/day) for *kharif* and *rabi* crops for T-kothapally group

Parameters	Groundnut (*Kh*)	Pigeon pea (*Kh*)	Maize (*Kh*)	Tomato (*Kh*)	Groudnut (*R*)	Maize (*R*)	Tomato (*R*)
Water required m^3/ha	69	67	69	72	79	59	74
Irrigation frequency, days	11	17	18	6	10	22	6
Number of irrigations required	10	10	6	23	12	6	24
Total Water requirement for 9.72 ha, m^3	671	648	671	700	765	573	714
Water requirement for 2.43 ha, m^3	168	162	168	175	191	143	179
Water requirement for 7.29 ha, m^3	503	486	503	525	574	429	536
Number of sections	4	4	4	4	4	3	4

CONCLUSION

Success of the CBSIS is possible if all the community members are satisfied by getting the optimal yields. So, the present study assessed the operational schedules to utilize the pumped water efficiently and without any bias. Optimal operational plans for *kharif* and r*abi* are assessed and recommended. The sprinkler nozzles which are being adopted are discharging more water in less time and leaving swampy areas, also 50% overlapping is ideal for uniform water distribution. The basic infiltration rate of the soil was used as a guide to select a sprinkler with a discharge rate lower than the infiltration rate (25-45 mm/day), hence it is recommended to change the sprinklers heads which suits the infiltration rate. Comparing the three groups, Mahabubsubhani group has 87% of NBWG area, where as Eedulavanka 50% and in Tkothapally 75%. Following the recommended schedules, it will cover 100% of the area irrespective of BWG and NBWG, as Mahabubsubhani group can irrigate 14.7 ha/day whereas Eedulavanka group 6.26 ha/day and T-Kothapally group 4.7 ha/day. It is advisable to diversify the crop and adapt drip irrigation system at least in bore well growers' fields. Crop diversification is recommended by strictly following the operating schedules will result in increase in area of coverage and improvement in yields and returns.

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