Assessment of Crop Water Requirements for Kulsi River Basin

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Abstract- The crop water requirement is a vital part for design and planning of an irrigation system. FAO (1984) defined crop water requirements as 'the depth of water needed to meet the water loss through evapotranspiration of a crop, being disease-free, growing in large fields under non restricting soil conditions, including soil water and fertility, and achieving full production potential under the given growing environment'. It is essential to have a clear idea about the optimum water requirement for proposed crops under adaptable climatic conditions. For an irrigation system optimal crop water requirement is a main aspect of the design and management of irrigation system. The optimal crop water requirement mainly depends upon the accurate estimation of evapotranspiration and crop coefficient. CROPWAT 8.0 is used for determination of crop water requirement in combination with CLIMWAT 2.0 for the proposed Kulsi River basin. Water requirement for the proposed crops have been calculated from the evaporation and rainfall data of meteorological station Guwahati which is extracted from CLIMWAT2.0. The total irrigation requirements has been estimated to be 586.63 Mcm The maximum area under cultivation at a time is worked out as 20500 ha which is considered as the Net Irrigation Area.

***Keywords: CLIMWAT, Crop Water Requirements, CROPWAT, Evapotranspiration, Effective Rainfall,* Irrigation Requirements**

I. INTRODUCTION

The irrigation water provided to various crops is based on the crop water requirement of respective crop. The crop water requirement (CWR) is one of the most important aspects of water management in a Command Area. Knowledge of crop-water requirements is crucial for water resources management and planning in order to improve water-use efficiency [1]. Crop water requirement is directly related to evapotranspiration (ET). Evapotranspiration (ET) is a combination of the water evaporated from the soil surface and transpirated through the plant. The most common technique to estimate ET is based on the *Kc* approach where the *ETc* is calculated by using standard agro-meteorological variable and a crop-specific coefficient, the crop coefficient *Kc*, which should take into account the relationship between atmosphere, crop physiology and agricultural practices.

A CROPWAT is a decision support system developed by FAO. The main functions of CROPWAT are to calculate reference evapotranspiration, crop water requirements, crop irrigation requirements and to develop irrigation schedules under various management conditions. CLIMWAT 2.0 is a climatic database used in combination with CROPWAT and allows the calculation of crop water requirements, for a range of climatological stations worldwide. CLIMWAT provides long-term monthly mean values of seven climatic parameters, namely: Mean daily maximum temperature in °C , Mean daily minimum temperature in °C , Mean relative humidity in % , Mean wind speed in km/day , Mean sunshine hours per day , Mean solar radiation in MJ/m2/day , Monthly rainfall in mm/month , Monthly effective rainfall in mm/month and Reference evapotranspiration calculated with the Penman-Monteith method in mm/day.

For the calculation of reference evapotranspiration, monthly climatic data (temperature, relative humidity, wind speed, sunshine hours, rainfall) are to be used as input data. The programme requires the crop data such as growth stages, Kc factors, root zone depth and allowable soil moisture depletion factor to calculate the crop water requirements on a decade (10-day) basis.

II. LITERATURE REVIEW

For proper planning of irrigation schemes and irrigation scheduling under different meteorological situations, the clear idea about crop water requirement is essential. For estimation of crop water requirement it is very essential to estimate correct crop evapotranspiration which again depends on reference evapotranspiration and crop co-efficient [2]. In his study, a suitable experimental model was presented for evaluation of crop coefficient fortnightly for various crops under a particular season. He made an endeavor to compare the approach with the approach developed by FAO. If climatic data can be collected accurately then Penman-Monteith method is better than Hargreaves method for calculation of reference evapotranspiration[3]. [4] Estimated the crop water requirements in an .agro-ecological unit of Kerala. They

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used CROPWAT 8.0 for estimation of crop water requirements, net irrigation demands, gross irrigation demands and irrigation scheduling for different crops grown in the area with the available climatic data. [5] CROPWAT derived a composite interrelationship among meteorological, crops and soil characteristics for management and planning of irrigation system. To evaluate the evapotranspiration, irrigation scheduling and crop water requirements under various cropping pattern CROPWAT is an essential tool. The objective of the study was to introduce CROPWAT simulation model developed by Food and Agricultural Organization (FAO) under irrigated and rainfed situations for maize crop and to obtained essential information in irrigation planning. [6] Explored the stakeholders of the Holetta River of Ethiopia and evaluated the water requirement for irrigation for main crops cultivated in the catchment. They used questionnaires for collection of information about the river users, main crops cultivated by using irrigation and total area coverage. For estimation of crop water requirements for major crops CROPWAT was used and calculated the total irrigation requirement for the crops. **[7]** Calculated the crop water requirements using Penman method with acquired crop coefficients. The results obtained by Penman method were compared with the method derived by Farbrother (1970). It was found that the penman method was more accurate than Farbrother method for estimation of total crop water requirements. [8] Enumerated that for proper practice of irrigation, irrigation scheduling and optimum use of limited water, a comprehensive knowledge is essential on crop water requirements. [9] Carried out on study on methodology of estimation of crop water requirements for some major crops in Mahanadi-Kathjori-Devi delta of Orissa. They outlined that the effective rainfall and irrigation water requirements is the basic criteria for the development of the model. CROPWAT model was used for calculation of crop reference, actual evapotranspiration and irrigation requirement of rice. The climatic, crop and soil data were extracted with the cowpat model as per FAO-56[10].

III. ABOUT THE BASIN

The Kulsi Basin is a Brahmaputra Sub-basin. The Kulsi basin area is falls in the Kamrup (Rural) district of Assam, India. The basin is enriched by Kukurmara River, Central Kulsi, Kharkhari channel. These rivers are rivulets of Kulsi river. There is also significant command area between Kulsi and Brahmaputra embankment on the North. The Command area starts from Just beyond west of Mirza town located about 40 Km from Guwahati. Important towns in the command on National Highway-37 include Chaygaon and Kukurmara which are 60 Km and 54 km from Guwahati. The area is bounded by undulating Reserve Forest area on the South, embankment of Brahmaputra River on the North, Rampur Village on the east and Deochar/Goroimari Road on the West. Chaygaon is an important township within the command area. The command area falls between the Latitude 25°59'41" N & 26°07'48" N and Longitude between 91°13'10" E & 91°28'46" E.

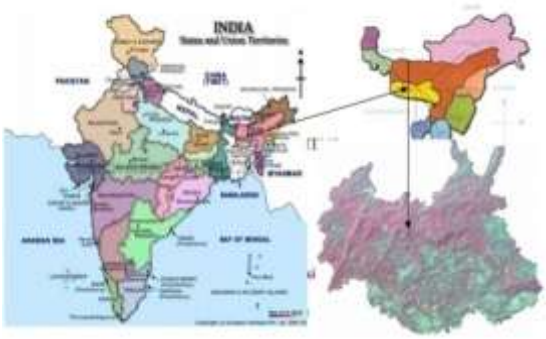

Fig-1: Location Map of Kulsi Basin

In the command area, presently there is no irrigation scheme. The proposed command area is presently fully dependent on rain fall for agricultural activities. Rain is the only source to meet the crop water requirements. This has left the farmers no choice on selecting the crops. Assured irrigation facility will encourage the cultivators to adopt the proposed cropping pattern including Rabi and other cash crops besides the traditional crops. As learnt from the local public as well as Government of Assam, the public of the area has been demanding for irrigation facilities since long time past. As such, this project will enable them to take up cultivation of other varieties of crop, which was not possible to cultivate due to non-availability of assured irrigation facility.

The Kulsi basin falls within the Climatic Zone No-1 which comprises of North and North-East part of India, adjoining part of Nepal, Bhutan, Bangladesh and North Myanmar. In this zone, the rainfall generally occurs in the monsoon period of June to September while the months from November to February are generally dry. Occasional rainfall occurs in the month of May as well as October. Tropical storms and depression affect the weather in this Zone during the months from June to September. In the months of April and May, this zone (i.e. the eastern parts of longitude 85^0 E) experiences pre-monsoon thunderstorm. In these months, the western half of the zone experiences day temperature upto 30^0C. Considering the above conditions, the zone is termed as "Tropical Monsoon Climate". Therefore, Pre-monsoon and monsoon crops are grown primarily in the area as rainwater is available during the period. However, cash crops and oilseeds requiring less water are also grown during autumn and winter months.

IV. CROPPING PATTERN

Net Command area i.e 20500 ha is proposed to be brought under irrigation through the proposed scheme. At presently only rain-fed cultivation is done in entire command area. There will be a net increase of 20500 ha in the irrigation facilities due to the project. The traditional cropping pattern can be modified with the introduction of assured irrigation facilities.

On introduction of irrigation, more areas can be brought under agriculture and cropping intensity can be raised to 226.82 %. Presently, most of the farmers raise only one rice crop. Due to lack of irrigation, rabi crops are grown on very limited area and that too with traditional crop varieties and practices. The Agriculture Department, Government of Assam was requested by the Brahmaputra Board to provide a modified cropping pattern suitable for Kulsi Command area with assured irrigation facilities and also to furnish a

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crop calendar. The Agriculture Department, Government of Assam has suggested a cropping pattern keeping in view of the above factors in conformity with the norms currently being followed by the Agriculture Department, Assam. The proposed cropping pattern is given in **Table 1** below.

V. AGRO-CLIMATIC CONDITION OF THE BASIN

1.1 Average Annual Rainfall

There is no rainfall data available in the catchment. The data maintained by Gopinath Bordoloi International airport, Guwahati is closest to the command area. According to the data available, the average annual rainfall of Kulsi command is 1747.54mm based on the available records of daily rainfall data for the period from January 1982 to August 2012. The seasonal distributions of rainfall in Kulsi command are as below–

Season	Rainfall in mm
Pre monsoon (March to May)	500.5
Monsoon (June to September)	1073.7
Post monsoon (October-November)	73.0
Winter (December to February)	35.5

Winter: The winter season sets in December and ends in February. This is the coldest season. The weather changes due to passage of western disturbance over the region. Winter rainfall is quite low in the area.

Summer: The summer season begins in March and continues up to May. In this season, occasionally marked instability develops in atmosphere and severe thunderstorms occur, sometimes preceded by dust squalls. Rainfall increases both in quantity and frequency, as the season advances and generally associated with thunderstorms and squalls. Hailstorms occur sometime in the season especially in hills during the month of March and April.

Monsoon: The monsoon sets in the last week of May or in early June. It is generally occurs due to depression in the Bay of Bengal. Subsequently, a series of such depression forming at the head of the Bay of Bengal moves towards inland. It gives spells of continuous and moderate to heavy rain over the basin. The monsoon withdraws in the last week of September or first week of October.

Autumn or Post Monsoon (October to December): This season begins in October and ends in December. There is almost no rain except for first fortnight of October. During this period the climate is neither very cold nor hot. However, in the high altitude upper reach of the sub basin, the climate becomes quite cold towards December end.

5.2 Temperature

There is no weather station situated within the command area. The nearest operational weather station available is at Gopinath Bordoloi International Airport, Borjhar which is located within 30 Km of the east end of the command area. Therefore, very accurate and long period data is available not only for maximum-minimum temperature but also for relative humidity. In general, the temperature in this sub-basin varies from 14^0 C to 39^0 C during summer and 7^0 C to 29^0 C during winter.

5.3 Humidity

The climate of this basin is generally very humid. There is no meteorological centre in the basin for observation of humidity. In Brahmaputra valley, humidity is high at a place where forest cover and vegetation cover is relatively more. Humidity data is available only in respect of Guwahati which is the nearest meteorological centre to the basin.

5.4 Cloud cover

As per the recorded data of the cloud cover, it is observed that excepting for the month of January, February, November and December, it is very difficult to find a fully sunny day in the area. The sun shines brightly during months of January, February, November and December but in rest of the months remains mostly cloudy.

5.5 Wind velocity

The wind velocity in the area is found to vary between 3.3 m/s to 0.1 m/s. The month of March and April remains relatively windy.

5.6 Evaporation

There is no meteorological center for taking evaporation data within the Kulsi basin which are related with temperature and humidity. The Meteorological Centre at Guwahati Airport maintained by IMD where the evaporation data is available is the nearest station and is suitable for use in the irrigation planning of the project as the station is adjacent to the command of Kulsi Multipurpose project. The average annual loss due to evaporation is 1370.01mm of which 65.05% occurs during the months of March to September. The seasonal evaporation loss and their percentage to annual loss are as below:

Winter (December to February	265.88mm (19.4%)
Pre-monsoon (March to May)	390.6mm (28.51%)
Monsoon (June to September)	500.7mm (36.54%)
Post monsoon (October to Nov)	212.83mm (15.53%)

VI. SOIL SURVEYS

Soil survey for the command area has been conducted for examining its suitability regarding its agricultural potential and engineering behavior. The soil survey to furnish basic information of soil and its resources of the command for intensive agricultural use was conducted by soil survey wing of the Agricultural Department, Government of Assam in association with North Eastern Hydraulic and Allied Research Institute (NEHARI) during 2002. From the survey, it is seen that 3 (three) series of soils have been identified - Kulsi-1, Kulsi-2 and Kulsi-3 series. Each of the three series contains silty, sandy and clayey loam.

6.1.1 Total Available Soil Moisture (TAM)

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Considering the extent and variation in soil type (i.e Sandy loam to Sandy clayey loam), total available moisture is considered to be 150 mm/m.

6.1.2 Maximum Rain Infiltration Rate

The maximum rain infiltration rate 80 Mm/day has been used for the analysis.

6.1.3 Maximum Rooting Depth

Maximum rooting depths is resemblance with the genetic characteristics of the crop. The maximum rooting depth is considered as per FAO.

6.1.4 Initial Soil Moisture Depletion (% TAM)

For the analysis works, 40% initial soil moisture depletion is considered. It is expressed as a depletion percentage from field capacity.

6.2 Crop coefficient (*Kc)*

The Kc for a given crop changes over the growing period as the groundcover, crop height and leaf area changes. Four growth stages are recognized for the selection of Kc: initial stage, crop development stage, mid-season stage and the late season stage. The K_c values for each crop is considered as per FAO.

6.3 Monthly reference evapotranspiration (ET_O)

Monthly reference evapotranspiration (ET_O) is obtained according to penman-monteith method using CROPWAT 8.0 (Table-3). The crop water requirements for the proposed crops have been calculated with the help of CROPWAT. The total irrigation requirement for various crops per decades of a month is tabulated in the table 4.

Table-1: Cropping pattern for Kulsi basin

Crop	Crop Period	Proposed area(Ha)	Percentage of NIA (Considering NIA = 20500 ha)
Pre-Kharif (Summer Paddy)			
HYV Boro (Mashuri, Joymoti, Jyotiprasad)	1st Dec to 30th April	4000	19.51
HYV Early Ahu (IR-50, Luit,Kanaklata & China-63)	1st Feb to 10th June	2000	9.76
Hybrid – Arise 644 & PCA-832	11th Dec to 10thMay	4000	19.51
Autumn Paddy			
HYV Regular Ahu	11th March to 10th July	4000	19.51
Summer Vegetable	11th Feb to 20th May	4000	19.51
Jute	10th March to 10th July	1000	4.88
Kharif (Winter Paddy)			
HYV- Ranjit, Bahadur, Mashuri	11th June to 10th Nov	8000	39.02
Black gram & green gram	11th August to 20th Dec	1000	4.88
Vegetable	11th July to 20th Oct	7000	34.15
Rabi			
Potato	21st Oct to 31st Jan	4000	19.51
Rape seed, Linseed	21st Oct to 31st Jan	3000	14.63
Maize, Pea, Onion & Garlic	11th Sept to 20th Feb	3000	14.63
Annual Crop			
Sugarcane	1st Feb to 20th Dec	1500	7.32
Total		**46500**	**226.82**

VII. CROP WATER AND IRRIGATION REQUIREMENTS

For calculating the crop water requirements for various crops the data to be incorporated in CROPWAT step by step depending on the cropping programme**.** The crop data required are the crop planting dates, the crop coefficient (Kc) values at the different growth stages, the length of growth stages, the crop rooting depth at the different growth stages, the allowable soil moisture depletion levels and the yield response factors (Ky). After the input of the crop data, CROPWAT proceeds to calculate the crop water and irrigation requirements of the given cropping pattern, using the entered crop data and the ETo and effective rainfall values calculated earlier. The calculation of crop water requirements is done on a decade (10-day period) basis. For reasons of simplicity, all months are taken to have 30 days, subdivided into 3 decades of 10 days each.

The monthly rainfall data extracted from the CLIMWAT 2.0 software for the climate station Guwahati is used in COPWAT 8.0 for calculation of effective rainfall. Table-2 shows the effective rainfall for Kulsi Basin.

Table-2 : Effective rainfall for Kulsi Basin, computed by CROPWAT 8.0

MONTHLY RAINFALL DATA		
CLIMATE STATION : GUWAHATI EFF. RAIN METHOD : USDA S.C. METHOD		
Month	Rainfall (mm/month)	Effective rainfall (mm/month)
January	9.0	8.9
February	18.0	17.5
March	51.0	46.8
April	159.0	118.6
May	219.0	142.3
June	320.0	157.0
July	359.0	160.9
August	243.0	148.5
September	182.0	129.0
October	86.0	74.2
November	23.0	22.2
December	7.0	6.9
Total	**1676.0**	**1032.7**
Eff rain form : P_{eff} = (P x (125 - 0.2 x P)) / 125 for P <= 250 mm P_{eff} = 125 + 0.1 x P for P > 250 mm		

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Table-3: ETo for Kulsi project computed by CROPWAT 8.0

MONTHLY REFERENCE EVAPOTRANSPIRATION ETo ACCORDING PENMAN-MONTEITH							
COUNTRY: INDIA 1942			STATION: GUWAHATI				
	ALTITUDE- 54.0 M		LONG-91.58 ^{0} E		LAT-26.1^0 N		
Month	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m²/day	ETo mm/day
January	10.50	23.60	76.00	52.00	7.10	13.80	1.98
February	11.90	26.00	65.00	69.00	7.50	16.30	2.68
March	15.70	29.90	56.00	95.00	6.80	17.70	3.71
April	19.90	30.70	64.00	147.00	6.70	19.30	4.52
May	22.40	31.00	74.00	95.00	5.90	18.80	4.14
June	24.80	31.90	81.00	95.00	3.40	15.20	3.57
July	25.30	31.70	81.00	69.00	3.30	14.90	3.46
August	25.40	32.10	82.00	69.00	3.80	15.10	3.49
September	24.40	31.40	81.00	69.00	4.50	14.90	3.36
October	21.90	30.20	81.00	69.00	6.30	15.30	3.18
November	16.80	27.50	82.00	69.00	7.50	14.60	2.61
December	11.80	24.40	83.00	51.00	7.00	13.00	1.95
Average	**19.20**	**29.20**	**76.00**	**79.00**	**5.80**	**15.80**	**3.22**

Table-4: Crop water and Irrigation Requirements for Kulsi basin

MONTH	PERIOD		IRR. REQD(MM)	AREA(HA)	IRR. REQD (HAM)	IRR. REQD (Mcm)/Dec	Monthly Irr.Requirement (Mcm)
Jan	1	10	224.00	15000	3360.00	33.60	94.13
	11	20	208.00	15000	3120.00	31.20	
	21	31	195.50	15000	2932.50	29.33	
Feb	1	10	172.10	14000	2409.40	24.09	86.61
	11	20	242.70	18000	4368.60	43.69	
	21	28	121.50	15500	1883.25	18.83	
Mar	1	10	205.00	15500	3177.50	31.78	162.9
	11	20	301.90	20500	6188.95	61.89	
	21	31	337.70	20500	6922.85	69.23	
Apr	1	10	188.40	20500	3862.20	38.62	57.75
	11	20	79.00	20500	1619.50	16.20	
	21	30	14.30	20500	293.15	2.93	
May	1	10	7.40	16500	122.10	1.22	5.72
	11	20	0.00	12500	0.00	0.00	
	21	31	36.00	12500	450.00	4.50	
Jun	1	10	0.00	8500	0.00	0.00	00.0
	11	20	0.00	14500	0.00	0.00	
	21	30	0.00	14500	0.00	0.00	
Jul	1	10	0.00	14500	0.00	0.00	00.0
	11	20	0.00	17500	0.00	0.00	
	21	31	0.00	16500	0.00	0.00	
Aug	1	10	0.00	16500	0.00	0.00	00.0
	11	20	0.00	17500	0.00	0.00	

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	21	31	0.00	17500	0.00	0.00	
Sep	1	10	0.00	17500	0.00	0.00	00.0
	11	20	0.00	20000	0.00	0.00	
	21	30	0.00	20000	0.00	0.00	
Oct	1	10	13.80	20000	276.00	2.76	20.93
	11	20	31.80	20000	636.00	6.36	
	21	31	67.50	17500	1181.25	11.81	
Nov	1	10	90.80	17500	1589.00	15.89	48.15
	11	20	158.90	9500	1509.55	15.10	
	21	30	180.60	9500	1715.70	17.16	
Dec	1	10	213.40	13500	2880.90	28.81	110.46
	11	20	248.50	17500	4348.75	43.49	
	21	31	254.40	15000	3816.00	38.16	
			3593.20		**58663.15**	**586.63**	

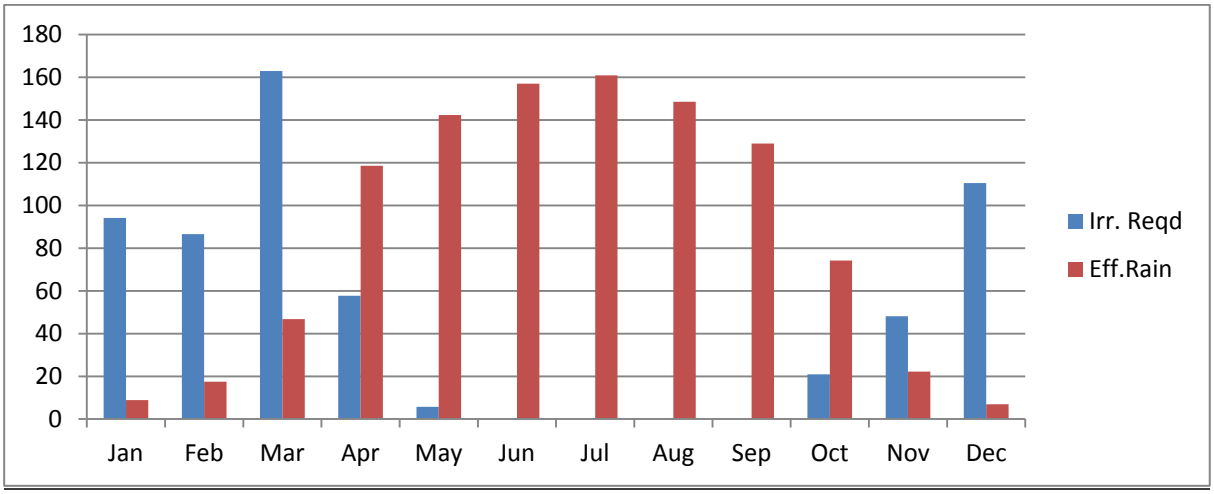

Fig-2: Showing monthly Irrigation requirements and Effective rainfall

VIII. CONCLUSION

Estimation of accurate crop water requirement is very essential for proper planning and management of irrigation project. The Kulsi irrigation project is proposed by the Agricultural Department, Assam. Presently there is no irrigation project in the basin. The aim of the present study is to calculate the crop water and irrigation requirements for the basin. For finding out the irrigation water requirements, the total available moisture is considered as 150 mm/m, the maximum rain infiltration rate is taken as 80 Mm/day, maximum rooting depths is considered as per FAO, initial soil moisture depletion is considered as 40%. Four growth stages are considered for the selection of Kc: initial stage, crop development stage, mid-season stage and the late season stage. The K_c values for each crop are considered as per FAO. The reference evapotranspiration is estimated based on FAO - Penman Monteith method from the evaporation and rainfall data of meteorological station Guwahati which is extracted from CLIMWAT 2.0. The total irrigation requirement has been estimated using CROPWAT 8.0 software. The calculation of crop water requirements is done on a decade (10-day period) basis as shown in table-4 above. From the fig-2, it has been observed that the monthly irrigation water requirement is maximum in the month of March. Generally the agricultural land is to be prepared for sowing crops in this period; hence maximum water is required for preparation of agricultural land. From Jun to September no irrigation water is required to be supplied, as this is the monsoon period and sufficient rainfall occurs in this period in Assam as well as North-East India. In the period from October to March there is scantly rainfall hence irrigation water is needed to be supplied for growing crops. The total annual irrigation requirements for the proposed cropping pattern is found to be 58663.15 Ham (586.63 Mcm). The maximum area under cultivation at a time is worked out to be 20500 ha which is considered as the Net Irrigation Area and maximum irrigation requirement at a time is assessed as 162.9 Mcm in the month of March.

REFERENCES

[1] Hamdy, A., and C. Lacirignola (1999). Mediterranean Water Resources: Major Challenges Towards the 21st Century. CIHEAM/IAM-Bari, 570 pp

[2] H.V. Hajare, (2007)," New Technique For Evaluation Of Crop Coefficients:A Case Study" Proceedings of

 DOI : 10.18231/2454-9150.2018.0470

the 2nd IASME / WSEAS International Conference on Water Resources, Hydraulics & Hydrology, Portoroz, Slovenia, May 15-17, 2007

[3] Peter Droogers and Richards G. Allen (2002), "Estimating Reference Evapotranspiration Under Inaccurate Data Conditions" Irrigation and Drainage Systems, February 2002, Volume 16, Issue 1, pp 33–45

[4] U.Surendran*, C.M.Sushanth, George Mammen, And E.J.Joseph (2015), "Modelling the crop water requirement using FAO-CROPWAT and assessment of water resources for sustainable water resource management: A case study in Palakkad district of humid tropical Kerala, India", International Conference On Water Resources, Coastal And Ocean Engineering (Icwrcoe 2015)

[5] Muhammad Nazeer (2009), "Simulation of maize crop under irrigated and rainfed conditions with cropwat model" Journal of Agricultural and Biological Science 2009 Vol.4 No.2 pp.68-73 ref.13

[6] Mahtsente Tibebe (2015), Water Demand Analysis and Irrigation Requirement for Major Crops at Holetta Catchment, Awash Subbasin, Ethiopia", Journal of Natural Sciences Research www.iiste.org,ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)Vol.5, No.15, 2015, 117

[7] A.W.Abdelhadi ,Takeshi Hata Haruya Tanakamaru AkioTada M.ATariq, (2000), "Estimation of crop water requirements in arid region using Penman–Monteith equation with derived crop coefficients: a case study on Acala cotton in Sudan Gezira irrigatedscheme" Agricultural Water Management, Volume 45, Issue 2, July 2000, Pages 203-214

[8] Zhang Weihua. Wei Chaofu(2015) "Irrigation water requirements of rice using Cropwat model in Northern Benin Abdel-Kabirou Bouraima",International Journal of Agricultural and Biological Engineering; Beijing Vol. 8, Iss. 2, (Apr 2015): 58-64.

[9] B. Panigrahi,S. D. Sharma and B. P. Behera (1992), "Irrigation water requirement models of some major crops", Water Resources Management, olume 6, Issue 1, pp 69–77

[10] FAO Irrigation and Drainage Paper No. 56 crop Evapotranspiration, "Guidelines for computing crop water requirements".

 DOI : 10.18231/2454-9150.2018.0470