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Crop Water Requirement in a Sub-Watershed of Mahabubnagar District of Telangana for Kharif Rice Cultivation using Geospatial Techniques

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ABSTRACT: In a sub-watershed of the Mahabubnagar district of Telangana state, India, the paper focuses on estimating the irrigation water requirements of paddy crops for the kharif season from 2019 to 2021. The Random Forest Classifier in Google Earth Engine has used Sentinel-2 to determine the area that is being used for paddy cultivation. Using the Hargreaves model, potential evapotranspiration (ETo) has been calculated. The crop coefficient (Kc) for paddy and potential evapotranspiration (ETo) were used to calculate the crop's water requirements (Etc). Utilizing gridded rainfall data from the CHRS (Center for Hydrometeorology and Remote Sensing) - PERSIANN-Cloud Classification System (PERSIANN-CCS 4km x 4km), effective rainfall was calculated. To calculate the amount of irrigation water needed, effective rainfall and crop water needs were taken into consideration. Net irrigation water need was calculated by assuming 30% losses. The amount of water needed for paddy is calculated by multiplying the paddy cropped area by the net irrigation water requirement.

KEYWORDS: Crop Water Requirement, Net Water Irrigation Requirement, Potential Evapotranspiration, Actual Evapotranspiration, Watershed.

I. INTRODUCTION

A significant amount of water is used in the irrigation of agricultural land. While, on average, more than half of it is lost due to inadequate water management and poor water transport technology. The need for an accurate calculation method of irrigation water requirements for diverse crops in various places with fluctuating climates has recently been brought to light by disputes over water rights (Mohammad Ismaeil Kamali, et.al. 2018).

In order to meet the rising population's need for food, which experts predict will double over the next 50 years due to limited water and land resources, farmers will need to boost their output from currently cultivated regions. In order to increase crop output and fulfil future food demands while ensuring food security, irrigation systems will be crucial. To realise its full potential, the irrigation industry must be revived by implementing cutting-edge management techniques and reorganising its structure.

Crop evapotranspiration (ETc), which measures crop water needs, is influenced by the weather and the actual conditions of the crop (H. V. Parmar, et.al. 2016 and E. Adamala, et.al.2016). By multiplying potential evapotranspiration (ETo) with crop coefficient, crop evapotranspiration (ETc) can be calculated. Crop co-efficient is taken from FAO Irrigation and drainage paper 56 (Chapter 6 - ETc - Single crop coefficient (Kc). Kc is normally calculated using literature values and is influenced by the type of crop and the stage of growth (R. G. Allen, et.al. 1998).

With the use of remote sensing technology, ETc may be calculated at the local and regional levels in less time and for less money (R. Allen, et.al 2007 and J. Kjaersgaard, at.al.2011).

The purpose of this study is to estimate the volume of water needed in a sub-watershed in the Mahabubnagar District during the kharif season for the cultivation of paddy. Since paddy is the main crop in the area, this work is done to get a general estimate of how much water is required for paddy production.

II. STUDY AREA

One of Telangana's districts, Mahabubnagar has a total area of 5,111.848 square kilometres. It goes by the name of Palamoor. The name was altered to Mahabubnagar in recognition of Nizam of Hyderabad, Mir Mahbub Ali Khan Asaf Jah VI (1869–1911 AD). The district is located between the latitudes of 15° 55' and 17° 20'N in the north and the longitudes of 77° 15' and 79° 15'E in the east. On average, it is 498 meters above sea level (1,633 feet). The four types of soil present in this area are loam, clay-heavy, clay-light, and sandy-clay. The region selected for this work is a sub-watershed in Mahabubnagar District. The area of the sub-watershed is 247.73 square kilometers.

Figure 1. depicts the location of the sub-watershed in Mahabubnagar district.

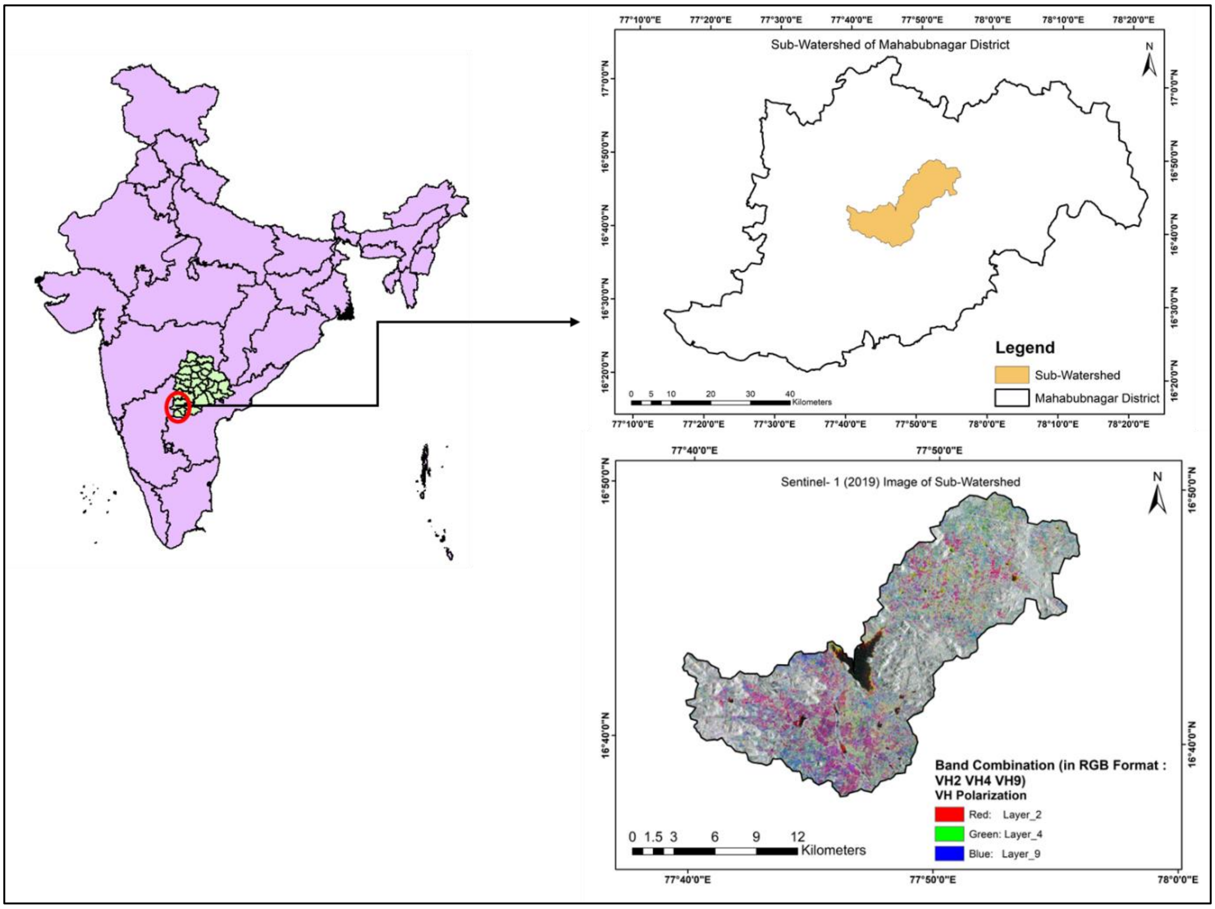

Figure 1. Location of Sub-Watershed (with Sentinel-1 2019 Image) in Mahabubnagar District

III. DATA AND METHODOLOGY

Data from a dual-polarization C-band Synthetic Aperture Radar (SAR) device is provided by the Sentinel-1 mission. Even in the presence of clouds, SAR equipment collect useful data both during the day and at night. The first new satellite of the GMES (Global Monitoring for Environment and Security) satellite series, Sentinel-1 is the European Radar Observatory. It was created and constructed by the ESA with funding from the EC (European Commission). Sentinel-1 is made up of a constellation of two satellites, Sentinel-1A and Sentinel-1B. Sentinel-1 Ground Range Detected (GRD) scenes are used for classifying monsoon crop from 2019 to 2021 (June to Oct). The instrument mode which is used is Interferometric Wide Swath (IW) with 10m spatial resolution. Since pre-processing of SAR imagery is time consuming in SNAP software hence ortho-rectified images are obtained using Google Earth Engine code editor.

Figure 2 shows GEE code editor for acquiring time series Sentinel-1 images from June to October.

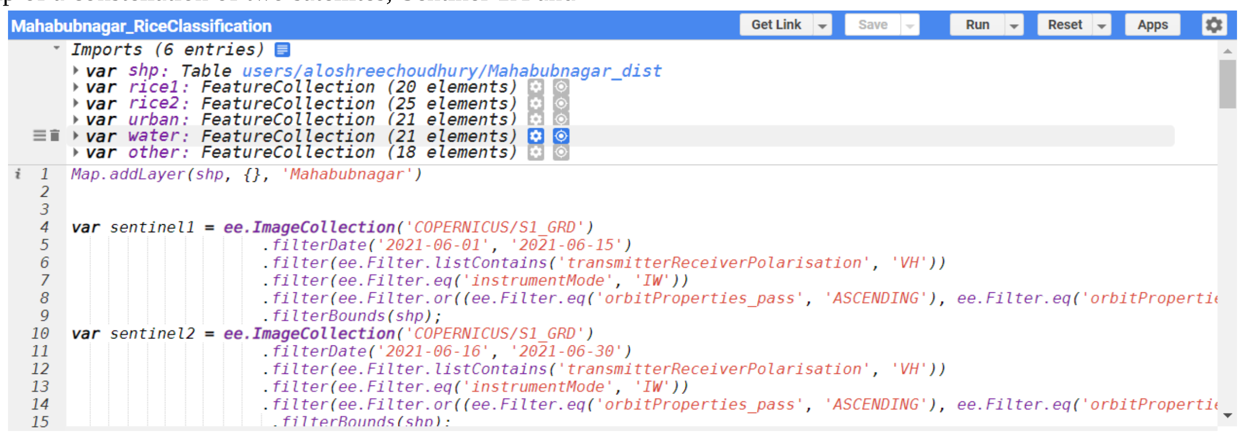

Figure 2. Google Earth Engine Code Editor

The image was captured using dual-band cross-polarization, vertical transmit/horizontal receive (VH). The time-series image has been stacked year-by-year independently over the period of June to October (2019 to 2021). The band combination utilised to obtain the RGB combination after stacking is VH2: VH4: VH9. Due to the fact that this combination will aid in classifying paddy. In the raw image the cyan colour indicates early sowing and magenta colour indicates late sowing (Figure 3). The classification technique involves the use of the random forest classifier. 20 signatures for each feature—rice, water and urban were considered. Rice was the end product after water and urban were removed. After classifying, the final output is paddy where early sowing is indicated in red and late sowing in green (classified image). Figure 3 indicates classified paddy of the sub-watershed.

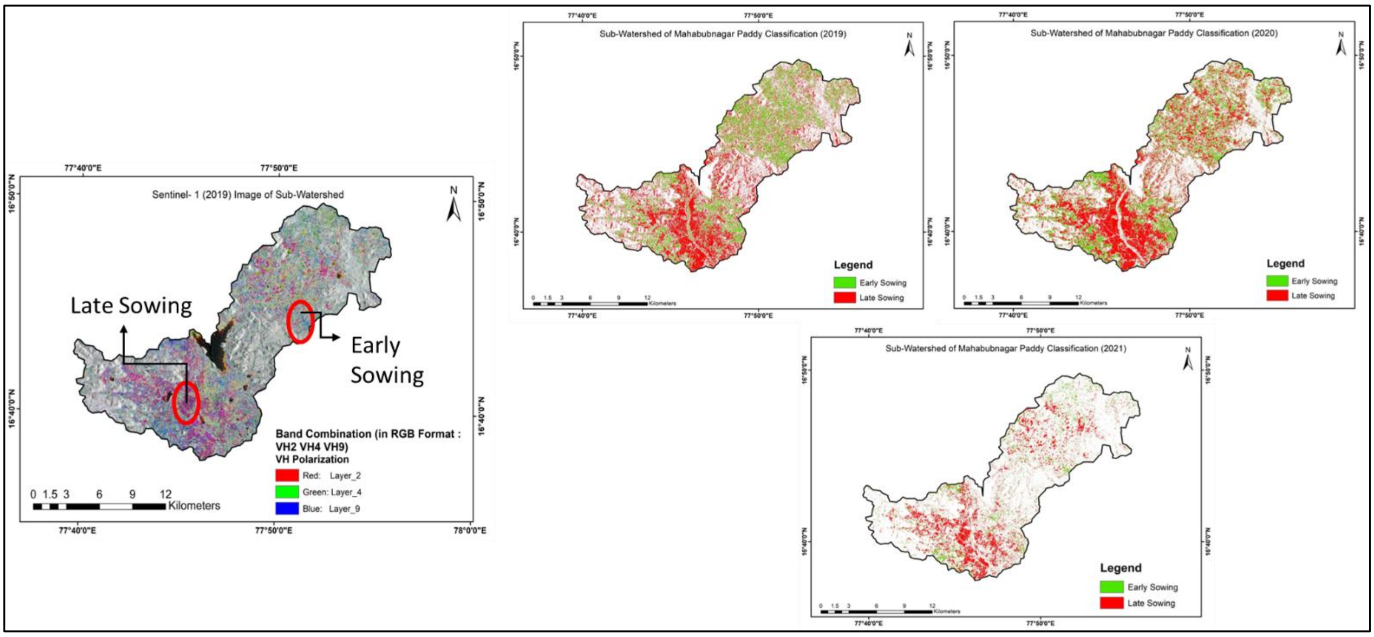

Figure 3. Stacked Sentinel-1 Image (L) and Paddy Classified Image (R)

The Center for Hydrometeorology and Remote Sensing (CHRS) at the University of California, Irvine developed the PERSIANN-Cloud Classification System (PERSIANN-CCS), a real-time global high resolution (0.04° x 0.04° or 4km x 4km) satellite precipitation product (UCI). The PERSIANN-CCS system makes it possible to classify cloud-patch features based on estimates of cloud height, areal expanse, and texture variability from satellite data (https://chrsdata.eng.uci.edu/). The monthly time-step from June to October was selected for the years 2019-2021. The KML boundary was used as extent to capture the extent and the gridded image was downloaded in .tif format. Mean rainfall over the time-series duration was estimated using Zonal Statistics in ArcGIS Software.

The Hargreaves equation was used to calculate daily potential evapotranspiration (PET) from meteorological data, as illustrated below.

$$ETo = 0.0023 * Ra * (Tmean + 17.8) * Tr\hat{}0.5 \quad (1)$$

$$Tr = Tmax - Tmin \quad (2)$$

where, ETo: potential evapotranspiration rate, Ra: extra-terrestrial radiation (calculated from latitude and time of year), Tmean: mean temperature, Tmax: maximum temperature, Tmin: minimum temperature (Hargreaves PET estimation model, 2009).

Crop coefficient (Kc) values for the paddy crop were acquired from FAO guidelines and multiplied by the potential evapotranspiration (ETo) in order to calculate the crop water demand (CWR), or in other words actual evapotranspiration (ETc).

$$ETc = Kc * ETo \quad (3)$$

The crop-coefficient of paddy in three different stages are shown in table below.

Table 1: Rice Crop Coefficient (Kc values)

Growth Stage	Crop Coefficient
Initial Stage	1.05
Mid Stage	1.2
End Stage	0.90 to 0.60

The rainfall data is downloaded from CHRS Portal. The mean rainfall over the years have been calculated as shown in table below.

Table 2: Mean Rainfall of the Sub-Watershed

Mean Rainfall (mm)			
Months	**2019**	**2020**	**2021**
June	167.0	137.3	148.7
July	202.3	279.9	223.4
Aug	167.8	202.9	111.3
Sep	233.2	428.7	191.1
Oct	225.4	145.1	100.9

The amount of irrigation water that must be applied is determined by the effective rainfall (ER) and the crop water requirement. Calculating the amount of water needed for irrigation (IWR) involves subtracting the effective rainfall (ER) from the crop water requirement which is actual evapotranspiration (Gaurav Pakhale, et.al.2010).

Table 3 shows actual evapotranspiration or crop water requirement over years from 2019 to 2021 for monsoon season.

$$IWR = CWR - ER \tag{4}$$

Table 3: CWR or Actual Evapotranspiration over years for Sub-Watershed

Months	2019	2020	2021
June	3.2	5.7	7
July	7.2	9.2	9.6
Aug	9.6	9.8	9.3
Sep	10.5	9.9	11.5
Oct	8	10.8	7.5

Effective rainfall (or precipitation) is determined by subtracting actual evapotranspiration from total rainfall. Table 4 depicts effective rainfall of the sub-watershed.

Table 4: Effective Rainfall

Effective Rainfall (mm)			
Months	**2019**	**2020**	**2021**
June	163.8	131.6	141.7
July	195.1	270.7	213.8
Aug	158.2	193.1	102.0
Sep	222.7	418.8	179.6
Oct	217.4	134.3	93.4

The total amount of water to be provided to crops throughout their life cycles, taking into account infiltration losses into the sub-soil and conveyance losses, is known as net irrigation water requirements (NIWR). Field losses and conveyance losses are estimated to account for 30% of the irrigation water needs.

$$NIWR = IWR + Losses \tag{5}$$

IV. RESULTS

The paddy classification was carried out in Google Earth Engine (GEE) for the sub-watershed for the years 2019, 2020 and 2021 for monsoon season. The area includes 8982.57 ha in 2019, 9306 ha in 2020 and 3681.374 ha in 2021 respectively.

Using the Hargreaves approach, the daily potential evapotranspiration was determined. For the three years

(2019-21, June – Oct) the daily values were combined to provide monthly values.

Table 5 indicates monthly PET for the sub-watershed.

Table 5: Monthly Potential Evapotranspiration (PET)

PET mm/day			
Months	**2019**	**2020**	**2021**
June	24.1	19.2	19.7
July	12.7	12.9	14
Aug	12.7	12.8	12.5
Sep	14.8	13.6	15.8
Oct	11.3	18.2	12.2

Figure 5 shows variations of PET in the sub-watershed for paddy.

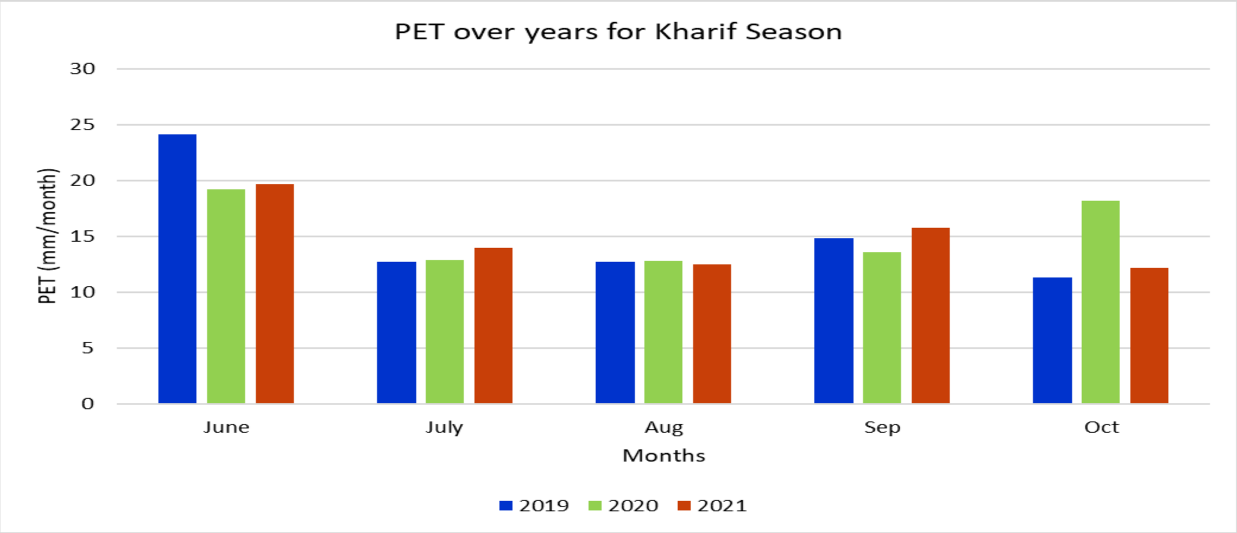

Figure 4: Variations of PET over years for Kharif Season in Sub-Watershed

From the graph above, it can be seen that the potential crop evapotranspiration peaks at the beginning stage during June, in the month of July-August, is slightly reduced at the growing stage, and finally shows an increasing trend at the late-season stage due to the higher-than-average temperature (Sep-Oct).

Calculating the crop's monthly water needs involved multiplying the PET by the crop coefficient values (Figure 5).

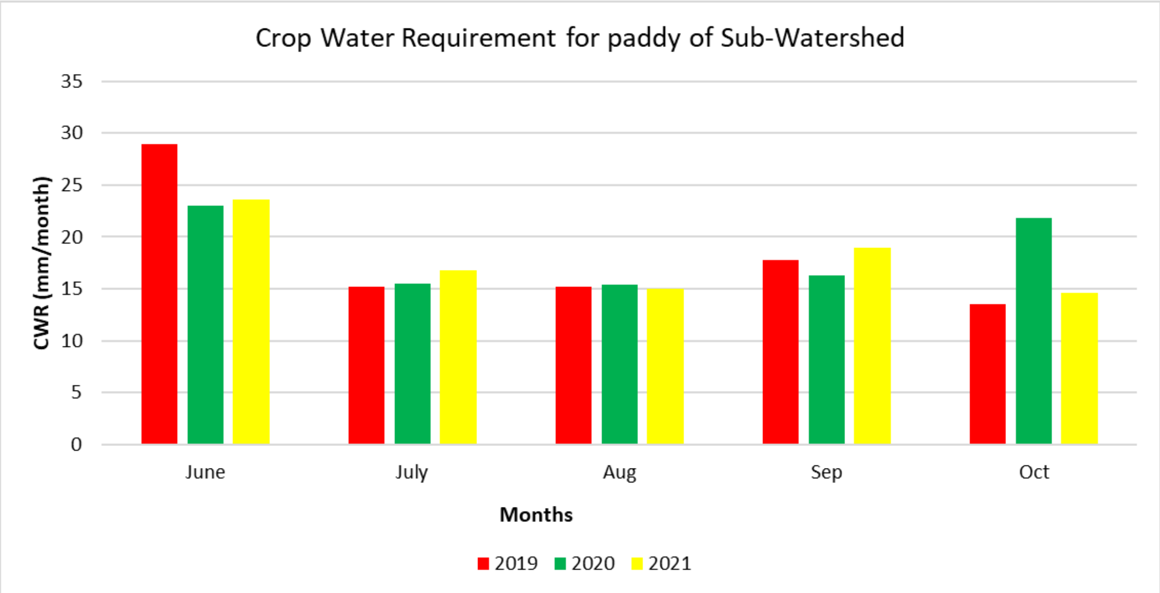

Figure 5: Variations of CWR for paddy over years during kharif season

At the initial stage CWR is more as paddy is transplanted in standing water. July- Aug shows water requirement is stable. During the month of September, water requirement gradually increases.

The CWR and effective rainfall are used to compute the irrigation water requirement (IWR). Below are the estimated irrigation water requirements (IWR) for the paddy crop in the sub-watershed of Mahabubnagar District (Table 6, figure 6).

Table 6: Irrigation Water Requirement for paddy

Months	2019	2020	2021
June	134.9	108.6	118.0
July	179.9	255.2	197.0
Aug	142.9	177.7	87.0
Sep	205.0	402.4	160.7
Oct	203.9	112.5	78.7

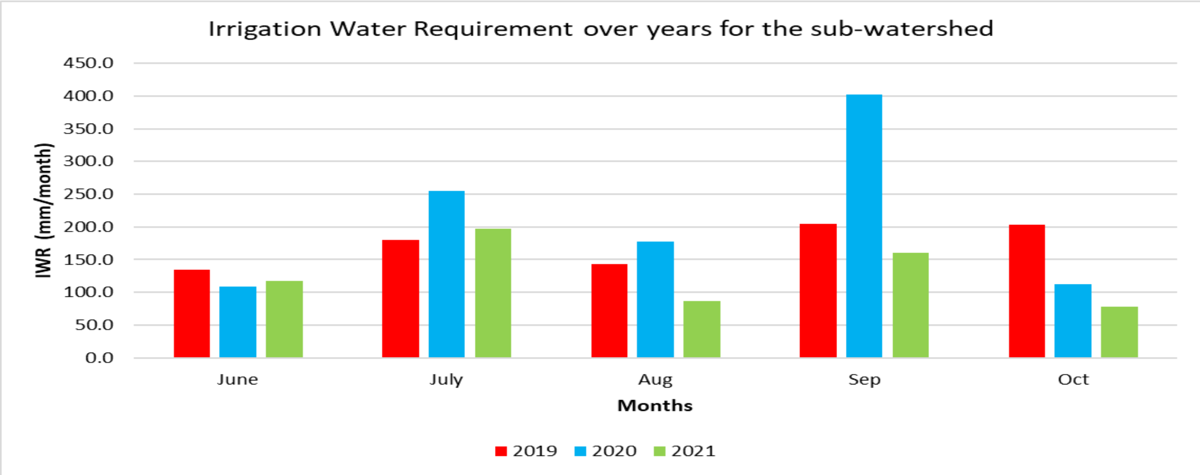

Figure 6: Variations of IWR during kharif season over years

As paddy is grown in kharif season, it needs more water for its growth. Sep 2020 shows maximum IWR, rainfall was high during that time. Effective rainfall during that time was 418.8 mm.

The net irrigation water requirement (NIWR) for the paddy crop was determined using an assumption of 30% conveyance and field losses (table 7).

Table 7: NIWR for paddy for sub-watershed

Months	2019	2020	2021
June	175.3	141.2	153.4
July	233.9	331.8	256.2
Aug	185.8	231.0	113.1
Sep	266.5	523.2	208.8
Oct	265.0	146.2	102.4

To calculate the amount of water needed for the kharif season in the sub-watershed, the net irrigation water need was multiplied by the paddy crop area (table 8).

Table 8: Volume of water needed for paddy

Months	2019	2020	2021
June	15.75	13.14	5.65
July	21.01	30.87	9.43
Aug	16.69	21.50	4.17
Sep	23.93	48.69	7.69
Oct	23.81	13.61	3.77

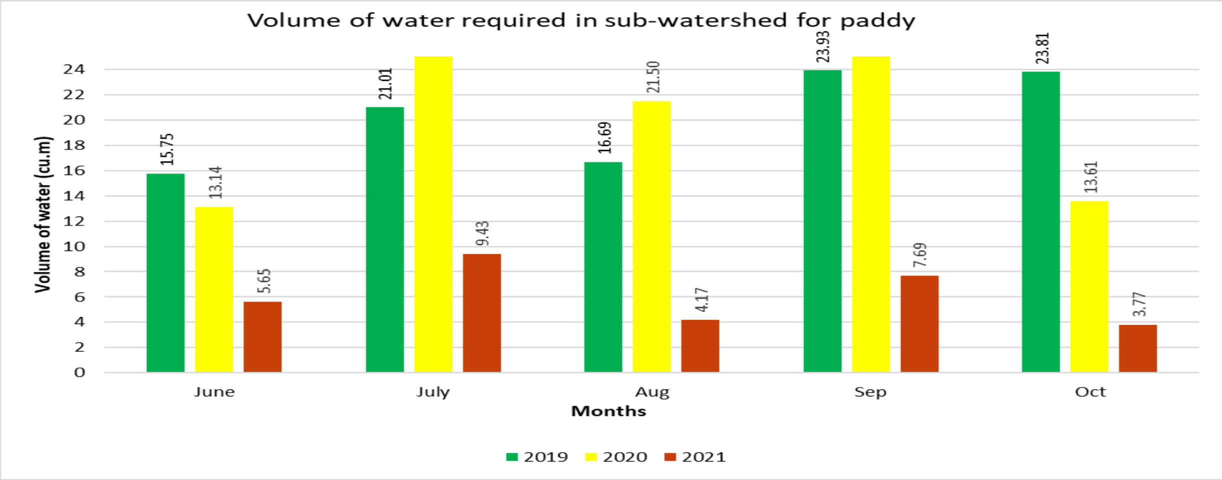

Figure 7: Volume of water required for sub-watershed over years for kharif season

V. CONCLUSION

The current work demonstrates that agricultural water requirements and irrigation water requirements may be estimated using a remote sensing and GIS integrated approach. The research area's need for paddy water increased during the sowing stage as paddy is sown in puddled water and over the season the water requirement is constant.

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