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Developing Water Management Strategies using Water Consumption Uniformity, Relative Evapotranspiration and Crop Water Productivity

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Abstract

Accurate and reliable information on irrigation practices and crop water use is essential for evaluating and improving existing water management strategies. This study assesses irrigation equity, adequacy, and crop water productivity for two water-intensive crops—Jute and Rice—cultivated across West Bengal from 2012 to 2022. Actual crop evapotranspiration (ETa) was derived using the Google Earth Engine Evapotranspiration Flux product. Irrigation performance indicators were computed using Relative Evapotranspiration (RET) for equity and the Coefficient of Variation (CV) for adequacy. Crop type classification was carried out using the Random Forest Algorithm, a supervised machine learning technique. Crop water productivity (CWP) was estimated as the ratio of crop yield to crop water use, with crop yield variability inferred from Normalized Difference Vegetation Index (NDVI) patterns. For jute and rice, the relative errors in the evapotranspiration estimates ranged from 7–27% and 0–3%, respectively. Spatial fluctuation in ETa varied between 10% and 35%, reflecting substantial heterogeneity in water use across the study region. Higher values of RET indicate optimal irrigation, while lower values signify water stress. The analysis revealed that approximately 32.5% of the jute-growing area and 13% of the rice-growing area experienced excess water application, whereas 41.73% of jute and 37.30% of the rice areas were water-deficient. These findings indicate significant spatial non-uniformity in irrigation practices, which may contribute to localized water scarcity and reduced water-use efficiency if not addressed through improved water management interventions.

Keywords EEFlux: Irrigation efficiency: Crop water productivity: Water efficiency.

Introduction

Irrigated agriculture is the largest user of freshwater resources and accounts for 70% of all water withdrawals (FAO, 2020). Population growth and industrialization increase the need for more food production specially in irrigated agriculture with limited water availability. Irrigation performance needs to be assessed and aim should be to use every drop of irrigation water. Performance indicators have replaced traditional irrigation efficiency assessments as the mainstay of the irrigation performance assessment approach. Adequacy, equity, dependability, productivity, and sustainability-based performance metrics have been introduced. The RET was used to examine the effectiveness of irrigation and the severity of water shortages. Coefficients of variation for actual evapotranspiration were also utilized as an equity metric in many studies. Recently, productivity-based performance measures have also received more attention, especially in areas with scarce water resources (Li et al., 2024)). The CWP indicator shows how efficiently water is being used. CWP has previously been used to evaluate water conservation strategies at several scales, including the basin level (Liu et al., 2021).

Several researchers have analyzed that multispectral vegetation indices such as $NDVI$ or the Enhanced

Vegetation Index (EVI) for determination of water productivity of the irrigated crops using Earth Engine Evaporation Flux ($EEFlux$) (Gonzaler et al., 2009; Venancio et al., 2020; de Oliveira Costa et al., 2020; Saeed, 2021; Reyes-González, 2018). Further, numerous researchers have established relationships between $NDVI$ and crop biophysical variables such as basal crop coefficient, cover fraction and soil evaporation. A time series and testified in conjunction with the FAO-56 dual source technique, Landsat images from the 2002–2003 growing season were employed (Kustas et al., 2016; Fenner et al., 2019). In this study, using $EEFlux$, ET_a, $NDVI$ and crop yield information, the performance of irrigation metrics based on sufficiency, equity, and productivity was determined covering rice and jute crop lands in West Bengal for the seasons between 2012 and 2022.

Materials and Methods

Study Area Description

Sub-Himalayan region and Gangatic area of West Bengal covers 88752 km^2 of area. Around 9.2 Mm^3/year of irrigation water is being diverted from rivers and managed by the Teesta Barrage Project under the Government of West Bengal. Subarnarekha Barrage Project covers catchment area of 17498 km^2 and Kangsabati River Project covers catchment area of 36225 km^2 and having discharge of 5663 cumeq (Government of West Bengal, 2015). Major crops in the sub-Himalayan region are rice, maize, oilseeds, pineapple, citrus etc (in the season of kharif) and in the Gangatic region, sugarcane, cotton, tea, barley are grown. Study area for Jute was considered as 36,225 km^2 and 45,673 km^2 for rice. The location of study area is shown in Fig.1.

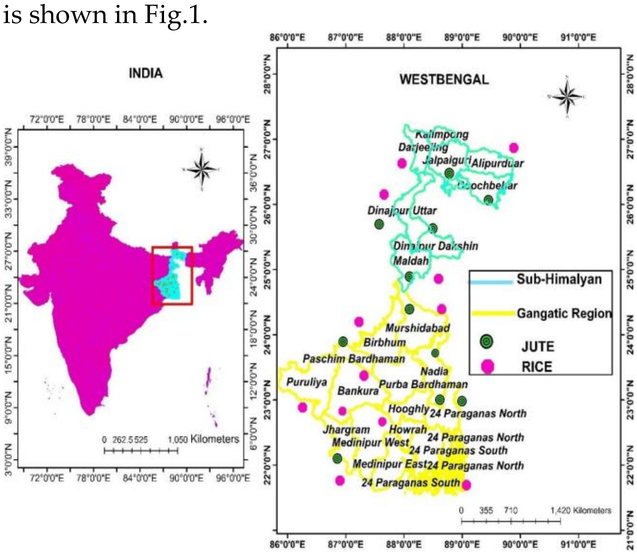

Fig. 1 Location of study area

Data Description

This study demonstrates the application of Google $EEFlux$ for assessing irrigation and evapotranspiration performance metrics. The analysis of actual evapotranspiration fluctuations, $NDVI$ mapping, and irrigation performance indicator with Google $EEFlux$ were carried out. Satellite data of different dates from the years 2012 to 2022 were used (Table 1) and the Q-GIS map (v 10.6) was used to analyze the landsat images in order to calculate the real evapotranspiration. The landsat images for the ET calculation were processed on $EEFlux$ metric version 3.1.2 on the $EEFlux$ website.

Table 1 Landsat satellite images (https://EEFlux-level1.appspot.com/)

Year	Acquisition Date	Satellite	Cloud Cover
2012	10-05-2012	LANDSAT 7 ETM	5%
2013	01-03-2013	LANDSAT 7 ETM	2%
	04-05-2013	LANDSAT 7 ETM	
2014	05-04-2014	LANDSAT 7 ETM	6%
	30-07-2014	LANDSAT 7 ETM	5%
2015	18-05-2015	LANDSAT 7 ETM	9%
	27-12-2015	LANDSAT 7 ETM	5%
2016	30-01-2016	LANDSAT 7 ETM	6%
	19-04-2016	LANDSAT 7 ETM	5%
2017	17-02-2017	LANDSAT 7 ETM	8%
	18-06-2017	LANDSAT 7 ETM	6%
2018	01-02-2018	LANDSAT 8 OLI	5%
	06-07-2018	LANDSAT 8 OLI	4%
2019	12-05-2019	LANDSAT 8 OLI	9%
	13-11-2019	LANDSAT 8 OLI	6%
2020	06-04-2020	LANDSAT 8 OLI	5%
	15-10-2020	LANDSAT 8 OLI	4%
2021	25-04-2021	LANDSAT 8 OLI	9%
	02-10-2021	LANDSAT 8 OLI	7%
2022	11-03-2022	LANDSAT 8 OLI	9%
	06-09-2022	LANDSAT 8 OLI	5%
	26-12-2022	LANDSAT 8 OLI	8%

The reference ET was provided on the $EEFlux$ platform. It provides a reference evapotranspiration (ET_r) - based standard ET dataset. Based on the Penman's Method, reference ET estimates were determined. The daily ET_r values were extracted from West Bengal's various climatic zones for May 2012 to December 2022. Crop zones must be mapped in order to measure and map the water consumption, yield and performance indicators particular to each crop. Sentinel-2 (Level-2A) images were obtained for crop mapping from the United States Geological Survey's (USGS) and Sentinel Scientific Data Hub website. Additionally, a comparison was made between the ET_o, which is multiplied by K_c in order to estimate the ET_c, and the ET calculated using the K_c-based method. The K_c values were considered as FAO guidelines (Table 2).

Table 2 k_c values for Jute and Rice at different phases (FAO, 1995)

Crop	Initial	Mid	Late
Jute	0.72-0.80	1.08-1.26	0.46-0.50
Rice	0.61-1.15	0.97-1.14	0.9-1.02

Crop Classification

Five crop groups grown in the State of the West Bengal were taken into account: Jute, Rice, Wheat, Oilseeds, and Barley. Mixed crops included all fruits, vegetables, and other crops. Urban areas, water bodies, wastelands, and woods are also included in the non-crop groups. Only Jute and Rice were used to interpret the results, despite the classification process including non-crop classifications. Sentinel images were examined for polygons that represented various types of crops, and a cropland map was used for the crop identification. NDVI and independent values from each of the bands served as features for the crop categorization. Jute and rice polygons were removed from the map and sampled for further study by examining several classifications. NDVI and independent values from each band served as features for the crop categorization. Jute and rice polygons were removed from the map and sampled for further study.

Image Processing

Using the Google $EEFlux$ program, the landsat images were processed for the ET_{rf} computations. Equ. 1 is utilized by the METRIC method, used by $EEFlux$, to determine the energy used during the evapotranspiration process:

$$LE = R_n - G - H \quad (1)$$

where, G is the soil heat flow (W m^2), H is the sensible heat flux (W m^2), R_n is the net radiation, and LE is the latent heat flux used by ET (W m^2). Equ. 2 is used to divide the LE by the latent heat of vaporization and the LE for each pixel from the precise instant of the satellite's passage to the value:

$$ET_{inst} = 3600 \times \frac{LE}{\lambda_{\rho w}} \quad (2)$$

The latent heat of vaporization (J/kg) and the density of water are all included in this equation. The resultant ET_{inst} is expressed as ET_{rf}, where ET_{rf} stands for the fraction of the reference ET_r, in accordance with Equ. 3. The reference evapotranspiration based on jute is known as ET_r in the ASCE Standardized Penman-Monteith equation. $EEFlux$ calculates ET_r from hourly and daily weather data into the Earth Engine using Equ. 3.

$$ET_{rf} = \frac{ET_{inst}}{ET_r} \quad (3)$$

ET_{rf} can be used to calculate the real ET for any time period by dividing it by the ET_r for nearby stations. The generated ET_{rf} maps were then mosaicked by Arc-GIS Pro for each image date. The missing data in the images from the Landsat-7 platform was also filled in using Arc-GIS Pro's tool.

Mapping the Seasonal *ET*

A collection of ET_{rf} maps of the study area were obtained from the $EEFlux$ platform to calculate the ET_a for the full crop season. For the first day between the image dates, linear interpolation was used to create daily ET_{rf} maps using the R - basic package. Two sets of the computations were performed, one for each of the two growth seasons of the crops under consideration in order to produce daily ET_{rf} maps. Jute's ET_a was calculated using interpolated images from May 2012 to December 2022, whereas rice's ET_a was calculated using interpolated images from October 2012 to December 2022. After interpolation, the daily ET_{rf} maps were multiplied by daily ET_r and the cumulative ET_a for the entire season was calculated using Equ. 4. For each day, the ET_{rf} from 18 weather stations was averaged.

$$ET_{period} = \sum_m^n [(ET_{rfi}) \times (ET_{rf24i})] \quad (4)$$

where, ET_{period} is the cumulative ET starting from day m to n, ET_{rfi} is the ET_{rf} for day i, and ET_{rf24i} is the 24 hours ET_{rf} for the day i.

NDVI and Crop Yield Mapping

The Landsat images for the years 2012 to 2022 were corrected for atmospheric conditions before further processing. The Digital Number (DN) was converted into surface reflectance using the USGS method. The metadata files were used to extract the local sun elevation, multiplicative and additive rescaling factors and other important information. The red band and NIR were then used to determine the $NDVI$. By breaking down the crop yield data from the crop report using Landsat $NDVI$ data as a bridge, the crop yield map was produced. Crop $NDVI$ was assumed to be directly connected to yield during the growing season. The $NDVI$ values of the crops would rise along with the agricultural produce. Weighting factor (WF) was established as the ratio of the pixel-wise $NDVI$ of the target crop to the mean $NDVI$ of the valley (Equ. 5). Equ. 6 was used to link WF to the observed yield data. The formula produced a crop yield map with a resolution of 30 m.

$$WF = \frac{NDVI_{pixel}}{NDVI_{avg}} \quad (5)$$

$$Yield_{pixel} = WF \times Yield_{obs} \times Area\ of\ one\ pixel \quad (6)$$

where, $NDVI_{pixel}$ and $NDVI_{avg}$ stand for the $NDVI$ of a single pixel and average $NDVI$ of the crop. A crop-specific $NDVI$ pixel map was obtained using the crop map. The yield in kg/m² for any particular pixel of the crop is called to as $Yield_{pixel}$, while the yield as observed in the is referred to as $Yield_{obs}$.

Methodology

The amount of vegetation, albedo and surface roughness were determined by $EEFlux$ using the landsat thermal and short-wave infrared band. Using the grids meteorological data, the ET_a was created as a surface balance of energy residuals. The ET_{rf} represents the ET as a percentage compared to the reference ET_r. The Landsat 8 - Operational Land Imager (OLI) and Landsat 7- Enhanced Thematic Mappers (ETM) were employed. By using all the collected satellite image and interpolation using Arc-GIS 10 and values were extracted to evaluate for further processing. For the crop-specific $NDVI$ assessment, images were extracted from the Landsat 7 ETM and Landsat-8 OLI satellites between 2012 and 2022. The near infrared (NIR) and red bands were mostly utilized to determine the $NDVI$. The $NDVI$ images were used to interpolate the crop yield data for the production mapping. Previous studies on jute have demonstrated strong relationships between NDVI (and related vegetation indices) and jute biomass or yield at key phenological stages, allowing NDVI-based metrics to serve as reliable proxies for yield (Murthy et al., 2022; Chakraborty et al., 2023; Rajpoot et al., 2019). Rice biomass and crop growth were evaluated to be substantially associated. The initial jute cutting season in West Bengal lasts around 45 days from September to October. As a result, May month is typically associated with the early developed stage of the jute plant. $NDVI$ average was determined in the rice fields over several months beginning in October. The crops normalized $NDVI$ of 0.85 was taken into account while $NDVI$ mapping.

Water Consumption Uniformity (WCU)

This is a measurement of irrigation equality, stands for water consumption uniformity. Measures of equality based on water usage rather than supply are regarded to be more relevant in countries with few water resources. The WCU was assessed by computing the CV of the ET_a at two different stages. This was accomplished using the zonal statistics tool in Arc-GIS10.8. In the crop map, there were a few scattered pixels that might have been caused by misclassification. The fields with less than 45 pixels (about 36,000 m²) were previously masked out from the crop-specific ET_a map in order to prevent the inclusion of pixels during the CV_w calculation. The threshold was established after visually inspecting the generated crop map. For fields larger than 36,000 m², the mean and standard deviation of ET_a were calculated.

Relative Evapotranspiration (RET)

When it comes to crop stress and water deficiency, RET is a crucial indicator of the field's water availability. The RET was calculated as the seasonal ET_a/ET_p ratio. With no restrictions based on plant development, ET_p refers to the potential amount of crop evapotranspiration under ideal crop growing conditions. In many aspects, it resembles the theoretically predicted ET_{ref}. As a result, seasonal ET_o and K_c values were used to write ET_p. The approach was put into practice using Arc-GIS Pro. The seasonal K_c for according to the weighted average of K_c determined depending on the length of the growing season for jute and rice ranged from 0.46 to 1.08 and 0.60 to 1.15, respectively.

Crop Water Productivity (CWP)

The CWP for the area was calculated using the crop-specific ET_a and yield maps from Equ. 7. Any unit differences between the yield map and ET_a were fixed in order to calculate the CWP in kg/m³.

$$CWP = \frac{Crop\ yield(ton/acre)}{ET_a(mm)} \quad (7)$$

To pinpoint the field or fields with the most room for development, the research area's CV of the CWP was determined. Whereas a location with a low CV of CWP demonstrates uniformity and little room for improvement, one with a high CV of CWP suggests potential for water management. To calculate the amount of CWP augmentation in the field under the present cropping condition, the correlations of CWP with ET_a and yield were also examined and evaluated.

Results and Discussion

Due to wide distribution in the field, jute was quite extensively mapped. Jute has an accuracy rate of 85.2%.

Comparisons between the projected and observed crop acreages revealed that the jute crop area was understated by 16.65% and by 4.38% of the rice. The predominate presence of jute in the field may be responsible for the marginally high differential in jute acreage. Therefore, the accuracy results for jute and rice were deemed appropriate for further investigation. Jute has shown spatial variation with the CV of 23.86%. The ET_a for jute ranged from 0.12 to 25.41 mm/day (Fig. 2). According to Fig. 3, the proportion of rice with the low ET_a, which ranges from 0.52 to 45.49 mm/day, is equivalent to that of rice. It was discovered that rice had a mean ET_a of 1126.95 mm and a CV of 21.36%. Figures 4 and 5 displays the yield maps for jute and rice. Jute yield estimation during the study period showed an average of 1.62 kg/m². The range of projected jute yield was quite close to the expected range. In a few locations in the western part of the state of West Bengal, yields were noticeably poor. It is important to note that the ET_a in this area was also low. Furthermore, it was discovered that areas with high jute yields also had high ET_a. The typical yield for rice was 3.175 kg/m². Although 89% of the region had more yields more, there was still a noticeable spatial difference between the fields after this point.

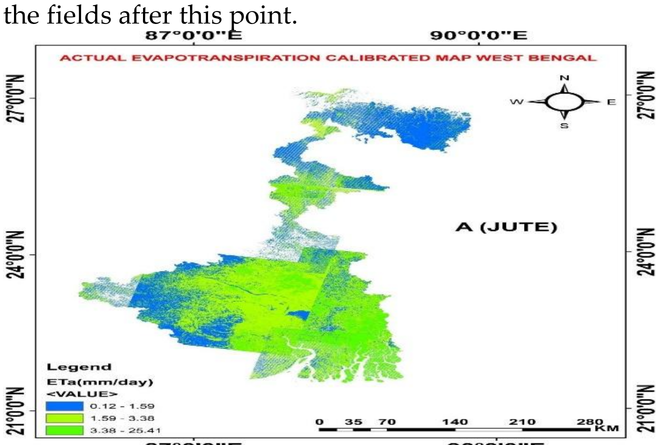

Fig. 2 Actual evapotranspiration of Jute crop in West Bengal

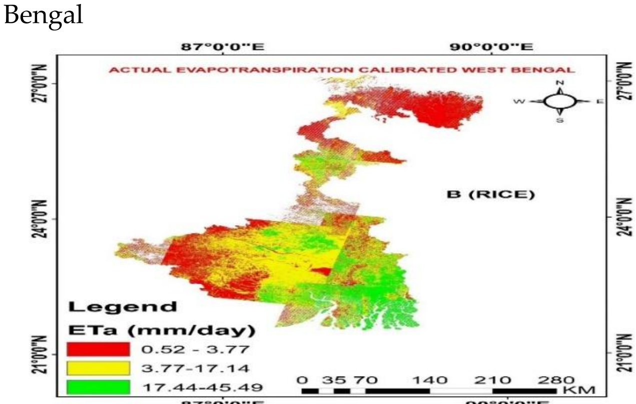

Fig. 3 Actual evapotranspiration of Rice crop in West Bengal

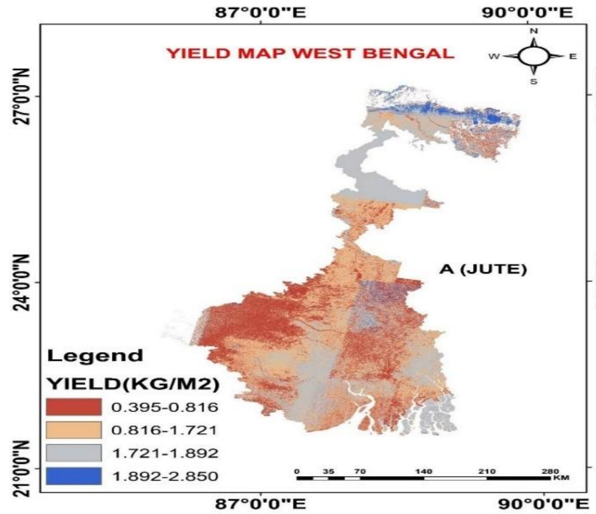

Fig. 4 Yield map of Jute grown in West Bengal

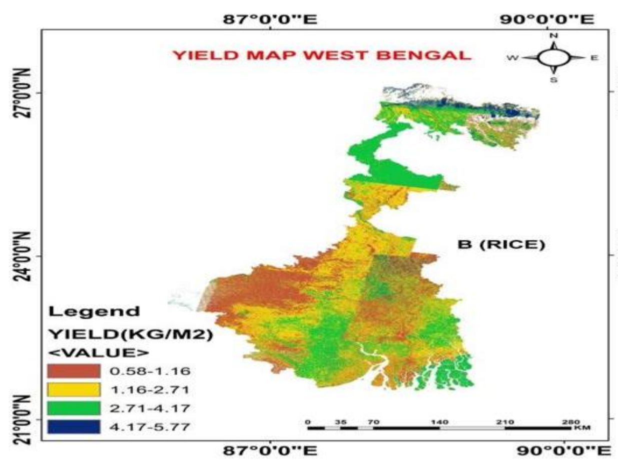

Fig. 5 Yield map of Rice grown in West Bengal

As per the study area in the Sub Himalayan region, value of ET_a varies from 700 to 2700 mm for Jute and 825 to 2950 mm for Rice and on other hand in Gangatic region variation of ET_a was observed as 628 to 2900 mm for Jute and 895 to 3250 mm for Rice. In terms of average ET_a per day for the Sub-Himalayan region, variation is from 0.12 to 3.24 mm/day for Jute and 0.55 to 32.51 mm/day for Rice, respectively. And for the Gangatic region, variation is from 4.30 to 20.67 mm/day for Jute, and from 16.44 to 45.90 mm/day for Rice, respectively. It can be seen that as the variation is basically based on the region and this is because of the climatic conditions of both the regions. The Gangatic region is most favorable as compared to Sub-Himalayan region because of water logging into the crop fields and drainage issues when compared to Sub-Himalayan region. For the Sub-Himalayan region, variation of yield is from 0.395 to 0.816 kg/m² for Jute and from 0.580 to 2.710 kg/m² for Rice, respectively. And for Gangatic region, variation of yield is from 0.816 to 2.850 kg/m² for Jute and from 1.160 to 5.770 kg/m² for Rice, respectively.

Water Consumption Uniformity (WCU)

The significant difference in water use between fields suggests a problem with irrigation uniformity. Jute's CV_w range varies from 5 to 36.1% (Fig. 6) with a mean of 9.73%. Despite a CV_w of up to 36.1% on the map, only 0.12% of the Himalayan region showed variances of more than 21%. Similar results were found for rice, where the CV_w of the seasonal ET_a varied from 0.2 to 42.5% with the average of 18.71% (Fig. 7). In our investigation, CV_w more than 10% were present in about 36.14% of the jute and 34.17% of the rice. Instead of the entire district, the highlighted fields may be the focus area for water management. The use of various tilling techniques, including levelling and sod bursting devices for accurate field grading can be credited with the state's overall higher homogeneity. Similar to this, higher CV_avalues for both the crop fields imply that there is only marginally enough irrigation equity between the fields. The repeated planting and harvesting of the jute fields may possibly be to blame for their high CV_a. Despite the fact that overall performance was excellent, there is still scope for improvement given the wide difference in performance across farms.

In the Sub-Himalayan region variation of CV_w is from 0.291 to 0.365 for Jute and from 0.127 to 0.277 for rice, respectively. For the Gangatic region, variation of CV_w was found to be from 0.076 to 0.151 for Jute and 0.268 to 0.425 for Rice, respectively. Water Consumption Uniformity (WCU) shows the variation of uniformity of water in a specific date in terms of coefficient of variation of water that is used in a given area. In the Jute field, variation is not much as compared to the Rice field in the Sub-Himalayan region and also in Gangatic region. It can be concluded that it is one of the most important performance indicators for water consumption evaluation.

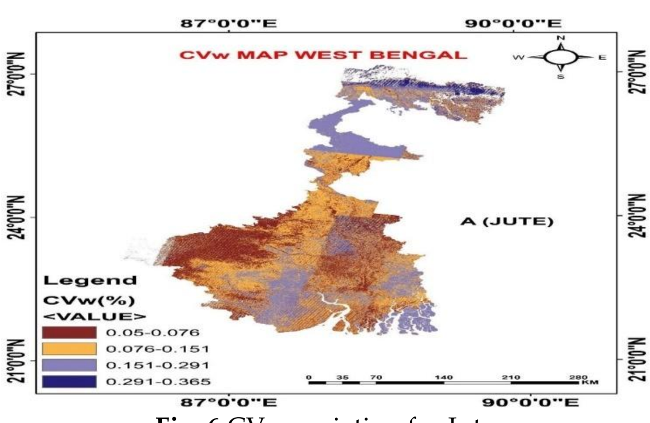

Fig. 6 CVw variation for Jute

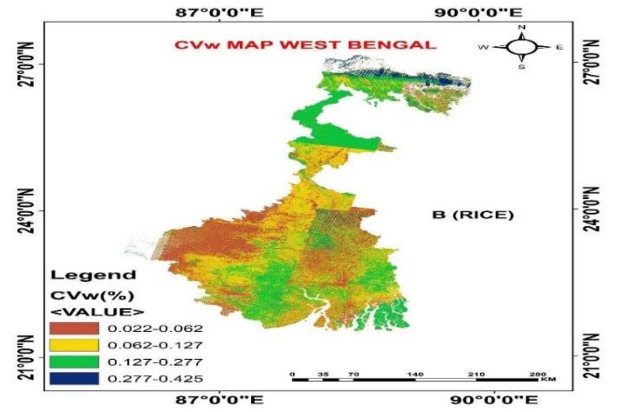

Fig. 7 CVw variation for Rice

Relative Evapotranspiration (RET)

The adequacy of the two crops, also known as the RET, was determined by dividing the theoretical ET by the actual ET. Figures 8 and 9 display the RET's spatial distribution. For Jute fields, average RETs were 0.844 and 0.797 in Sub-Himalayan region and 0.88 and 1.22 in Gangatic region. Also, for Rice, value lies from 0.33 to 0.56 in Sub-Himalayan region and 0.86 and 1.06 in Gangatic region. Under optimal growth conditions, the gap between the ET_a and ET_p must be smaller and the ratio would be close to 1. According to Roerink et al. (1997) values of 0.75 and above are considered appropriate for irrigated agriculture. More than half the area planted for both crops in the current research found RETs more than 0.75, indicating adequacy. Focus might be given to the farms where the RET is below the ideal level, where crops are suffering from water shortages and reduce production. RETs of greater than one was present in about 31.5% of the jute and 12% of the rice fields. These fields for rice are clearly concentrated on the state's northern side, while fields for rice in the eastern parts and a few in the eastern parts showed RETs larger than one.

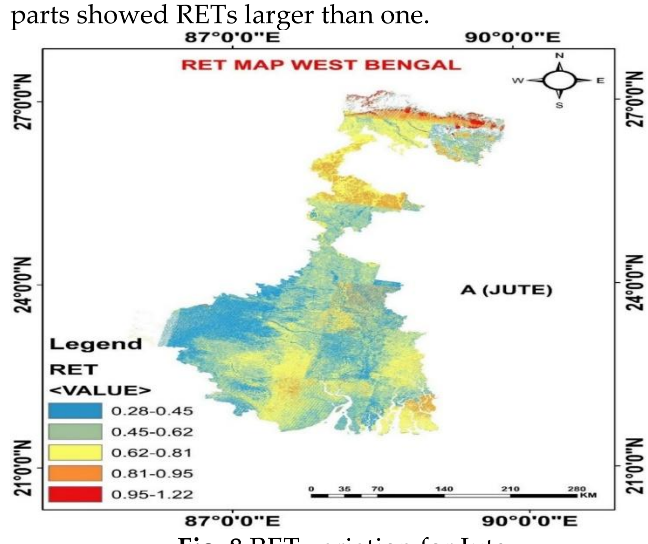

Fig. 8 RET variation for Jute

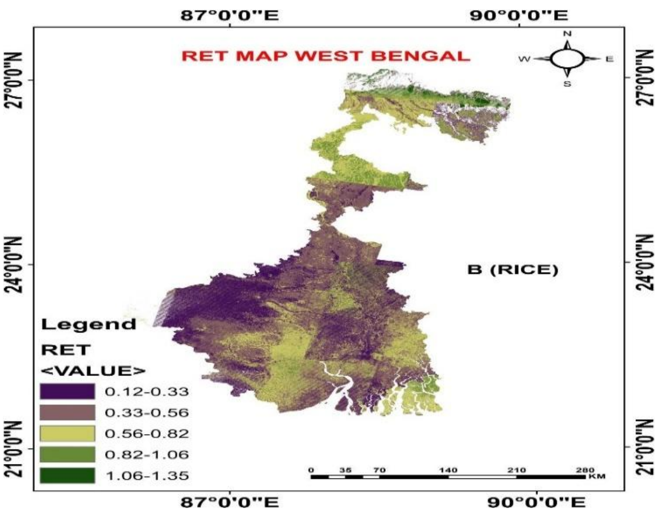

Fig. 9 RET variation for Rice

Crop Water Productivity (CWP)

In this study, the water productivity was calculated as the crop production divided by ET_a. The average jute CWP is 0.328 kg/m³, with the CV of 32.92%. During the classification, it was likely that the remaining fields contained mixed pixels from various crop types. With a lower CV (25.4%) than rice, the rice CWP produced an average of 2.387 kg/m³. This shows that even though these fields consume more amount of water than necessary, their high yields and high CWP compensate for this. Variation of CWP in the both regions was observed based on the both crops. For Jute, it varies from 0.259 to 0.594 kg/m³ in the Sub-Himalayan region whereas value for Rice varies from 2.33 to 3.60 kg/m³. On the other hand, in the Gangatic region variation is from 0.38 to 4.062 kg/m³ for Jute and 6.68 to 11.03 kg/m³ for Rice, respectively. There are considerable variations in the values of CWP as compared to Sub-Himalayan region for both the crops. The average CWP of Jute obtained in the study was close to the range of 0.38–0.43 kg/m³, however, for Rice this variation was from 2.33 to 11.03 kg/m³. The variation in the climate and productivity of Jute and Rice may have caused the differences.

Scope of Water Conservation

Because of the high CV of CWP for both jute and rice fields, there is a significant scope for CWP enhancement. Increasing the yield or keeping the yield constant while using less water can also lead to CWP enhancement. Random points were created from a matching spatial map in order to better comprehend the breadth of water saving through CWP enhancement. Scatter plots were then created between the CWP, yield, and ET_a in order to observe the relationship between them. It shows that the jute ET_a distribution range had a high yield for ET_a in the range of 0.12 to 25.41 mm/day. However, it is noted that the fluctuation declines and the yield remain consistently high for ET_a above 25.41mm/day. This suggests that, above this range, reducing the irrigation water amount would not have a major negative impact on the yield. Similar outcomes were seen for rice with modest yield distribution in the ET_arange of 0.52 to 45.49 mm/day.

For both the jute and rice crops, the relationship between the CWP and ET_a revealed that the CWP declines as the ET rises, especially for ET_a above 25.41 mm/day for jute and 45.49 mm/day for rice. In order to retain the yield while reducing water use over the aforementioned ranges, we discovered a range of CWP enhancement. The findings suggest that by lowering the $ET_a$to a range where the yield is not negatively impacted and the CWP is improved, it is possible to conserve about 51.47Mm³ of the irrigation water volume. The ET_a distribution range is from 700 to 2900mm for Jute and 825 to 3250mm for Rice in Sub-Himalayan Region and Gangatic region. The CWP falls as the ET increases, especially for ET as above 1500 mm for Jute and 1200 mm for Rice, according to the association between the CWP and ET_a for both crops. Therefore, CWP maintaining the yield by reducing the water use ranges to around 1500 mm and 1200 mm for Jute and Rice, respectively. Lowering the ET_a to a range where the yield is not negatively impacted, it is possible to conserve roughly 44.52M cu m of water for irrigation volume.

Conclusions

In this study, irrigation performance criteria based on equity, sufficiency, and water productivity were determined. To create ET_{rf} images of the IV, all Landsat 7/8 photos with low cloud cover were processed using the EE_{flux}platform. As measures of irrigation equality and sufficiency, crop water production, RET, and WCU were identified. The relationship between crop ET_a, yield, and CWP was also investigated to ascertain the degree of CWP augmentation and water saving. It was revealed that 36.14% of the rice fields and 34.17% of the jute fields displayed spatial differences where scope of water saving is significant. Water Consumption Uniformity varies from 0.291 to 0.365 for Jute and 0.127 to 0.277 for Rice in Sub-Himalayan area.

In Gangatic region, this varied from 0.076 to 0.151 for Jute and 0.268 to 0.425 for Rice. More than half of the fields have access to sufficient water, according to RET

(RET > 0.75). On the other side, 31.5% of the jute and 13% of the Rice were using more water than was necessary (RET > 1). The results showed that more than 11 million cubic meters of water might be saved by reducing water use in these regions. With a CV of 25.4% for rice and 32.92% for jute, the CWP's wide variance indicates a significant scope for improvement. By lowering the ET_a for Jute and Rice to around 1500 mm and 1200 mm, respectively, which will increase the CWP without lowering the yield, nearly 44.52M cu. m of water savings opportunities were revealed. Fields with high RET and inconsistent irrigation distribution were visually recognized. Similar to this, it was expected that there will be fields with huge CWP variations where significant CWP improvement may be obtained by lowering the variability.

The technique did not give comprehensive insight into the causes of the high variation or high-low values, but it did show the general picture of irrigation performance across the irrigation district. The effectiveness of water conservation in the state of West Bengal might be improved with the use of this knowledge. As per the findings based on the relationship between $\boldsymbol{ET_a}$ (Actual Evapotranspiration), Water Consumption Uniformity (WCU), Relative Evapotranspiration (RET) and Crop Water Productivity (CWP) values, it can be concluded that with comparison to Sub-Himalayan region scope of water conservation is high in Gangatic region in the state of West Bengal.

Salient conclusions drawn are given hereunder:

- Scope of water conservation is high in the Gangatic region as compared to Sub-Himalayan region.
- lowering the $\boldsymbol{ET_a}$ to a range where the yield is not negatively impacted and the CWP is improved, it is possible to conserve about 51.47M cu m of the irrigation water volume.
- By lowering the value of Relative Evapotranspiration, amount that can be conserved is 44.52 M cu.m of water in a given crop season in the Gangatic region.

By using Google Earth Engine Flux, it can be analyzed the scope of any area of any specific crop in a given time period.

Data Availability Statement

The datasets generated during the current study are available from the corresponding author on reasonable request.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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