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Research Article

Evaluation of Irrigation Application for Two *Rabi* Crops Grown in Coastal West Bengal using Agrometeorology and Remote Sensing

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ABSTRACT

In the coastal West Bengal, the principal crops in *rabi* season are rice and vegetables. Both the amount and timing of irrigation must be optimized for better yields of crops in this area. In this study, irrigation scheduling by farmers were evaluated for vegetables and the irrigation performance indices (IP) were computed for rice crop. Irrigation application (twice) on 20 and 60 days after transplanting (DAT), thrice on 20, 40 and 60 DAT, and four times on 15, 30, 45 and 60 DAT have resulted in better scheduling efficiencies for vegetables in all soils. Nikarighata and Tangrakhali soil series received higher irrigation water (>1000 mm) compared to the other soil series (~750 mm), and the growth performance of rice was high (average GVI = 0.40) in these two soil series compared to others (0.35 in Gosaba and 0.33 in Sonakhali). Water received by rice was marginally higher than supply to all crops (IP1 > 1.0) and the water demand was lower than the supply (IP2 < 1.0). Integration of agroclimatic data with satellite image showed an approximately 2860 ha-m surplus irrigation water for rice and 358.7 ha-m deficit water for the vegetables.

Key words: LISS-III, Vegetation index, Irrigation scheduling, Irrigation performance index

Introduction

Irrigation water is one of the critical inputs for agricultural production in semi-arid and arid parts in India (Sampath, 1991). Efficient water use in agriculture is made through optimum utilization of all available water resources to meet the crop water demand. Prior to such planning, it is important to quantitatively evaluate an irrigation system performance. Both the amount and timing of irrigation requires optimization for better crop yields. While the amount of irrigation depends on crop demand (climate and area specific), timing and frequency are dependent on crop growth stages and nature of the soil (Raut, 1998). A critical problem in irrigation management is to determine when and how much to irrigate. When the irrigation water supply is adequate, the farmer needs information on the optimum irrigation schedule to ensure the maximum water use-efficiency. Under inadequate supply of water, rationalizing the limited water distribution over the available land, applying water at critical growth stages and withholding irrigation at other stages are the possible options (Reddy and Reddy, 1995; Raut *et al*., 2001). Increase in agricultural productivity through irrigation management needs a blending of traditional methods with emerging technologies. Application of remote sensing techniques has the potential to provide quantitative, instantaneous, and non-destructive information on agricultural crops. Space-borne remote sensing satellite data can be used to disseminate relevant and adequate

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information over a large area at frequent intervals (Rao *et al.,* 1995), including crop area estimation (Ajay *et al.,* 1985). Crop water requirements may be combined with area of cultivation to estimate and cater the demand and supply of water in an area (Menenti *et al.,* 1989). Irrigation scheduling based on evapotranspiration values estimated from climatic data was helpful in developing efficient irrigation management practices for crops, because this approach is relatively simple compared to on site measurements (Menenti *et al*., 1986).

In this study, the irrigation performance of two crops, rice and vegetables grown in *rabi* season in the coastal West Bengal were assessed through irrigation scheduling efficiencies and irrigation performance indices using agro-meteorological and IRS-P6 LISS-III data.

Materials and Methods

The study area is coastal West Bengal (22.11-22.35° N and 88.50-89.00° E, Fig.1) comprising mainly three blocks, Canning 1, Basanti and Gosaba. The climate is sub-humid with hot summer and cold winter seasons. The annual rainfall was recorded as 2050 mm during 2011-12. The IRS-P6: LISS-III satellite data of 24th January, 2012 and 12 April, 2013 (path 108, row number 056) were procured from National Remote Sensing Centre, Hyderabad.

The area comprises of 4 soil series: Sonakhali (S), Gosaba (G), Nikarighata (N), and Tangrakhali

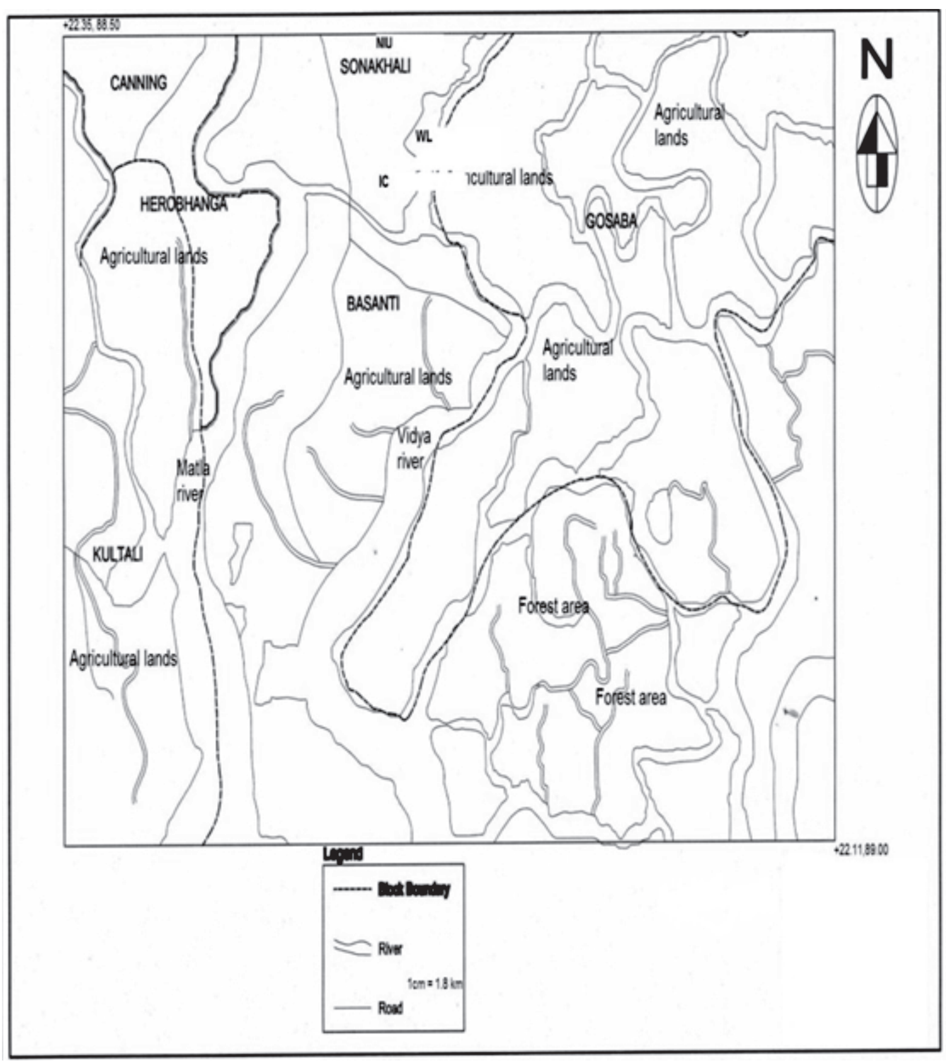

Fig. 1. The study area in coastal West Bengal covering three Blocks

Table 1. Textural class, available soil water and infiltration rate of soil series in the study area

	Soil series			
	Nikarighata	Tangrakhali	Sonakhali	Gosaba
Soil texture	Clay loam	Clay loam	Loam	Sandy clay loam
Available soil moisture (mm m^{-1})	230	240	250	280
Infiltration rate (mm d^{-1})	20	25	30	30

(T). Texture, available water holding capacity and infiltration rate of these series are given in Table 1. The soil series was considered as the unit for the study. Care was taken in selecting fields so that these could be easily identified in the satellite image. Fields were mostly irrigated using tube well, and the information on the type of pump, capacity, number of hours of operation and the number of irrigations were collected from individual farmers (application efficiency was taken as 100%). The locations of these fields were recorded with a hand-held GPS (accuracy 5 m).

Crop water requirements of rice and vegetables (brinjal and tomato) were determined from meteorological data by using Penman-Monteith method (FAO, 1993) method. CROPWAT 8.0 calculates irrigation requirement (mm d^{-1} and mm 10-d^{-1}) by simply subtracting effective rainfall values from the crop water requirement. In the present study, effective rainfall was calculated through United States Bureau of Reclamation method. The input meteorological data were collected from meteorological observatory of Central Soil Salinity Research Institute, Canning, West Bengal. The crop coefficients, rooting depth, water depletion level and yield response factors for computation of crop water requirements are given in Table 2 & 3. A maximum rooting depth of 150 cm and initial soil moisture depletion of 10% were considered for both the crops during calculation of scheduling efficiencies.

Green vegetation index (GVI) was derived from digital analysis of IRS-P6 LISS-III data using ERDAS Imagine-11 image analysis package. The index was calculated as: GVI = [(NIR – R) / (NIR + R)] * 127 + 128

The crop map was prepared by digitally classifying the multispectral image, and the location of the fields was verified with a hand-held GPS. Accuracy assessment was done for the supervised classified image by feeding (x, y) coordinates of 20 reference points in the field and their corresponding ground truth 'classes' against the MXL 'classes' obtained from the satellite image. To obtain areas under different crops (such as rice, vegetables, water body, bare soil etc.), supervised maximum likelihood (MXL) classification was done making different classes depending on spectral and spatial distances (15 and 10, respectively) and ground truth data. In GIS mode, the areas under different classes such as urban, bare soil, rice, vegetables etc. were obtained (Table 4).

Table 2. Crop coefficients, rooting and puddling depths, water depletion level and yield response factor for rice

Stage	Nursery	Land preparation		Growth stage				
		Total	Puddling	Initial	Development	Mid	Late	Total
Length (day)	30	20	10	20	30	40	30	150
$K_{c\ (wet)}$	1.20	1.05	1.05	1.10	-	1.20	1.05	-
Rooting depth (m)	-	-	-	0.10	-	0.60	0.60	-
Puddling depth (m)	-	-	0.40	-	-	-	-	-
Nursery area (%)	10	-	-	-	-	-	-	-
Critical depletion level	0.20	-	-	0.20	-	0.20	0.20	-
Yield response factor (Coeff.)	-	-	-	1.00	1.09	1.09	1.09	1.09

Source: FAO (1993)

Table 3. Crop coefficients, rooting and puddling depths, water depletion level and yield response factor for small vegetables

Growth stage	Initial	Development	Mid	Late	Total
Length (day)	20	35	40	35	130
K_c	0.70	-	1.05	0.95	-
Rooting depth (m)	0.25	-	0.60	0.60	-
Critical depletion level	0.30	-	0.40	0.50	-
Yield response factor (Coeff.)	0.80	0.40	1.20	1.00	1.0

Source: FAO (1993)

Table 4. Different classes obtained in MXL classified image and their respective areas

Class No.	Class category	Areas (ha)
1.	Urban	2449
2.	Bare soil	3599
3.	Fallow land	9468
4.	Rice	4785
5.	Vegetables	1889
6.	Water body	2205
	Total	24,395

Table 5. Major irrigation schedules for vegetables followed in the study area

No. of irrigation	Irrigation schedule (DAT)
Two	15,60 / 20,60 / 10,50
Three	15,30, 45 / 20,40,60 / 10, 30, 60
Four	15,30,45,60 / 20,40,50,60 / 10,15,35,65

DAT: Days after transplanting

Results and Discussion

Evaluation of irrigation performance

Irrigation performance in the canal command was evaluated with respect to time of application and amount applied in different soil series. Best time of irrigation application in different soil units was judged through efficiencies of irrigation scheduling in CROPWAT (Raut *et al.*, 2001), whereas sufficiency of irrigation amount, or otherwise, was judged through irrigation performance indices (Menenti *et al.*, 1989).

Evaluation of irrigation schedules

The farmers' irrigation schedules in the study area are shown in Table 5. Irrigation scheduling efficiencies for vegetables were higher in Gosaba soil series, followed by Sonakhali. Tangrakhali and Nikarighata soil series had low performance (Table 6). The higher irrigation scheduling efficiency could not be the only factor for higher crop growth because of several other factors e.g. varieties, pest and diseases, water quality, etc. The available moisture holding capacities (AWC) of Gosaba and Sonakhali soil series were higher (280 and 250 mm m^{-1}, respectively) compared to other two soil series (240 and 230 mm m^{-1}, respectively). The textures of the soils were sandy clay loam to loam. The higher AWC and medium texture of the Gosaba and Sonakhali soils might have resulted in higher scheduling efficiencies. The irrigation scheduling efficiencies for 4 number of application schedule were higher for all soils as compared to 3 and 2 times of applications. This could be due to precise amount of applications (40 mm) at critical growth stages in case of 4 applications, whereas in 3 and 2 applications, the amount of irrigation water was higher in each time (60 and 100 mm, respectively), and was thus, not effective in resulting high scheduling efficiencies. Delay in 1st irrigation by 5-6 days resulted in high scheduling efficiencies for all soils as the soil had enough moisture from rainfall during the month of transplanting (November, 1st week).With the increase in number of irrigations, there was an increase in scheduling efficiencies for all soil groups due to more frequent application with lower amount of water, allowing the crop to utilize water more efficiently.

The irrigation performance index IP 1, which is based on relative water distribution between

Table 6. Best irrigation schedules and efficiencies obtained in CROPWAT 8.0 for different soils

Best irrigation schedules	Schedule efficiency (%)			
Time in DAT	Nikarighata	Tangrakhali	Sonakhali	Gosaba
15,60	65.0	66.5	67.4	69.9
20,40,60	75.0	76.5	77.0	78.6
15,30,45,60	87.5	87.6	88.1	90.1

DAT: Days after transplanting

soil series, reveals that Nikarighata and Tangrakhali soils received higher amount of water (>1000 mm) compared to other soil series (average 750 mm). The growth performance of rice under these two soil series was high (average GVI = 0.40) compared to other two soil series (0.35 in Gosaba and 0.33 in Sonakhali). In all the cases, water received by rice was little higher than the supply (values > 1.0) (Fig. 2). The other irrigation performance index IP2, which is based on water requirement estimated from climatic data also shows that the rice crop received more water than the requirement (values<1.0). Both the indices relating water distribution equities among different soil series indicated that there was a surplus of water supply in the rice fields.

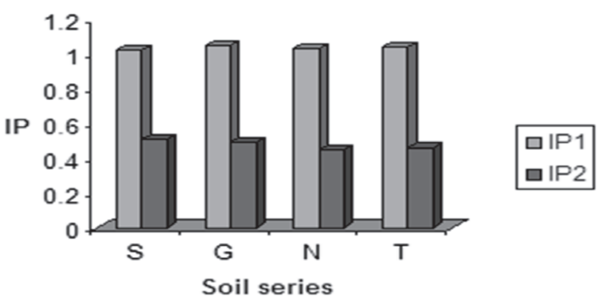

Fig. 2. Irrigation performance index (IP1 & IP2) obtained for different soils (S: Sonakhali, G: Gosaba, N: Nikarighata and T: Tangrakhali)

The GVI was negatively related with salinity of the soil (r=-0.29). The effect of salinity on GVI for the rice crop can be shown as GVI = 148.04 + (- 2.46) * EC.

Effect of irrigation and soil on GVI

The average GVI values significantly differed among four soils (p = 0.01). The total amount of irrigation applied also differed significantly among various soil series. Farmers in the soil series Nikarighata and Tangrakhali applied irrigation at a higher average rate (>1000 mm ha^{-1}) while the farmers in the soil series Sonakhali applied at the lowest rate of around 750 mm ha^{-1}. Effect of irrigation water for different soil groups on GVI is shown in Table 7. Again the response to irrigation differed among different soils. It is seen that Gosaba and Sonakhali soils had a higher intercept of nearly 0.04 and 0.01 GVI indicating the higher potentiality of these soils compared to others. However, Tangrakhali and Nikarighata soils showed high response to irrigation (r^2 = 0.80 and 0.77, respectively, significant at 0.1% level) while the response to irrigation was lowest (r^2 = 0.56) under Sonakhali. This may be due to the presence of high initial soil moisture or use of poor quality water in Sonakhali. Tangrakhali and Nikarighata soil series had highest average GVI (0.40) compared to others. In other words, the irrigation response was dominating the basic potential of the soil in the area (Table 6). It is seen that the GVI responded to improvement in irrigation equity judged through irrigation performance index IP1 and IP2 among the three soil series *viz*., Tangrakhali, Nikarighata and Gosaba, which was verified through April, 2013 data. While increase in IP1 was associated with

Table 7. Effect of different soil types on crop growth response (GVI) to irrigation

Soil series	Relationship	r^2
Sonakhali	GVI=0.014+8.98E^{-05} * I	0.56**
Gosaba	GVI=0.044+7.46E^{-05}* I	0.69**
Nikarighata	GVI=0.004+9.43E^{-05}* I	0.77**
Tangrakhali	GVI=0.005+9.59E^{-05}* I	0.80**

'I' is applied irrigation (mm); ** significant at 0.1% probability level

Table 8. Area and water requirements under rice and vegetable cultivation in 2011 obtained from integration of agroclimatic data and land use map

Crops	Rice	Vegetables
GIS classified area (ha)	4785	1889
Crop water requirements (mm)	702.9	322.8
Effective rainfall (mm)	84.6	12.9
Irrigation requirement (ha-m)	3360	585.4
Total supply (ha-m)	6220	226.7
Surplus / Deficit (ha-m)	2860	358.7

better irrigation, improvement in IP2 indicated more water demand and poor performance. Sonakhali soil performed poorly and under low irrigation equity yielded inferior crop growth (lower GVI).

Surplus and deficit of irrigation water

The IRS-P6 LISS-III data pertained to a period of mid-growth in rice and vegetables (24th January, 2012). The classified image resulted six classes: *rabi* rice, small vegetables, water body, bare soil, fallow land (rice stubbles) and urban area (Table 8). From a total area of 24,395 ha in the final map, area under *rabi* rice and vegetables were 4785 and 1889 ha, respectively. Since in the study area crop planting or sowing for a particular crop was similar, rate of crop development, length of growing season, irrigation after sowing and climatic conditions did not differ much, the crop coefficient values were taken same for that particular crop for whole area (FAO, 1974; FAO, 1993) (Table 2 and 3).

From the field survey, it was found that there was no considerable change in the cropping pattern in the last 10 years (2002-2012). Thus, rice and vegetable classes (areas) obtained through analysis of satellite data were merged with irrigation requirements of both the crops. This gave 3360 ha-m total irrigation requirements for rice and 585.4 ha-m for vegetables. The crop water requirement was 702.9 and 322.8 mm for rice and vegetable crops, respectively (Table 8). These data are in agreement with the findings of Panigrahi *et al*., 2010 who found that the water requirements of winter rice in the sub-humid regions of India were around 600-720 mm. The requirements for tomato crop were 277-284 mm and for other vegetables, 318 mm (Mishra *et al*., 2009*)*. A surplus of 2860 ha-m water for rice (adequate) and a deficit of 358.7 ha-m water (inadequate) for vegetables were obtained (Table 8).

Conclusions

The irrigation water in coastal West Bengal was 'adequate' for rice and 'inadequate' for vegetables. There were approximately 2860 ha-m water surplus for rice and 358.7 ha-m water deficit for small vegetables. Rice crops were cultivated in fields where there was presence of tube wells in close proximity. Water for irrigation was mainly drawn from deeper non-saline layers unaffecting or slightly affecting yields.

The crop inputs analyzed through remote sensing, GIS and CROPWAT indicated that further improvement in the performance of rice and vegetable growth in the study area could be possible at the present level of fertilizer application, mainly by increasing amount of irrigation water supply, enhancing more uniformity in irrigation distribution and reclaiming saline soil.

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References

Ajay, Gopalan, A.K.S. and Kamat, D.S. 1985. Discrimination of winter crops using temporal spectral profiles. *Int. J. Remote Sens.* **6**: 1575-1580.

FAO. 1974. Effective rainfall. *Irrigation and Drainage paper* No. 25, FAO, Rome.

FAO.1993. Climwat for Cropwat. *FAO irrigation and drainage paper* No. 46 & 49; FAO, Rome.

Menenti, M., Azzali, S., Leguizamon, S. and Collado, D.A. 1986. Multi temporal analysis of LANDSAT Multi-Spectral-Scanner (MSS) and Thematic Mapper (TM) data to map crops in the Po valley (Italy) and in Mendoza (Argentina). 7th Int. Symp. Remote Sensing for Resource Development and Environmental Management, 1986, pp. 293-299.

Menenti, M., Visser, T.N.M., Morabito, J.A. and Drovandi, A. 1989. Appraisal of irrigation performance with satellite data and georeferenced information. *Irrigation Theory and Practice* Pentech Press, London. pp. 785-801.

Mishra, J.N., Paul, J.C. and Pradhan, P.C. 2009. Response of okra to drip irrigation and mulching in coastal Orissa. *Ind. J. Soil Cons*. **37**:129-32.

Panigrahi, B., Roy, D.P. and Panda, S.N. 2010. Water use and yield response of tomato as influenced by drip and furrow irrigation. *Int. Agril. Engg. J.* **19**: 19-30.

Rao, V.V., Nayak, A.K., Kumar, P. and Chakraborty, A.K. 1995. Agricultural cropland inventory and assessment of water resources for water management in an irrigation command area – a case study. ISRS Silver Jubilee Symp., 1994-95, pp. 282-289.

Raut, S. 1998. Assessment of crop response to irrigation water distribution in a canal command area using remote sensing and GIS. Ph.D. Thesis, IARI, New Delhi. 65p.

Raut, S., Sarma, K.S.S. and Das, D.K. 2001. Evaluation of irrigation management in a canal command area based on agro-meteorology and remote sensing. *J. Ind. Soc. Remote Sens.* **29** (4):225-28.

Reddy, G.H. and Reddy, T.Y. 1995. *Efficient use of irrigation water*, Kalyani Publishers, pp. 16-18.

Sampath, R.K. 1991. A Rawlsian evaluation of irrigation distribution in India. *Water Res. Bull.* **27**: 745-51.

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