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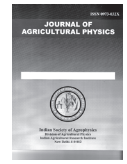

Managing Irrigation in a Canal Command Area Located in a Subhumid Region based on Agrometeorology and Remotely Sensed Land Use Map

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ABSTRACT

Efficacy of irrigation management of *rabi* rice and small vegetable crops grown in the Balipatna Canal Command area of Orissa (subhumid region) was done from land use map derived through supervised Maximum Likelihood Classification, SOI toposheets and field verification and from irrigation scheduling efficiencies obtained through FAO model CROPWAT 8.0. Irrigation scheduling efficiencies for vegetables were computed from crop coefficients, amount of water supplied at different growth stages, soil water depletion and crop water requirement. For computing water requirement of rice, factors related to land preparation, puddling and soil as suggested by FAO were taken into account. Agro-meteorological data in combination with land use map approximated the deficiency of applied irrigation amount as compared to requirement. Irrigation application at 25-85 Days After Transplanting (DAT), for two times of applications, 30-60-100 DAT for three, 20-40-70-100 DAT in case of four irrigations have resulted in better scheduling efficiencies for vegetables.

Key words: Irrigation water requirement, Scheduling efficiency, Land use map

Introduction

Irrigation water is one of the critical inputs for agricultural production in semi-arid and arid parts of the world (Sampath, 1991). It plays an important role in governing plant growth and optimum amount of irrigation is necessary to crops to be supplied at the right time to get better crop yields. While the amount of irrigation is dependent on the crop demand, climate and area under each crop, timing and frequency of irrigation are dependent on crop growth stages and nature of the soil (Raut *et al*., 2001). Optimum utilization of all the available water resources to meet the crop water needs therefore depends on planning of efficient water use in agriculture. Prior to such planning, it is important to understand how an irrigation system actually performs in quantitative terms. This is best done by matching demand for water in terms of crop water requirement and available supplies in time and quantity. It is also necessary to evaluate the efficacy of irrigation distribution and its impact on crop performance. To increase agricultural productivity through irrigation management, traditional methods need to be combined with the new emerging technologies. This requires a reliable information system and a package of efficient management practices. Application of remote sensing techniques has the potential to provide quantitative, instantaneous, and non-destructive information about agricultural crops. Data obtained from space borne remote sensing satellites can be used to obtain relevant and adequate information for a large area at frequent intervals (Rao *et al.,* 1995). In a canal command

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area two situations are generally faced by farmers (i) adequate water supply particularly in the head reaches of the canal and (ii) inadequate supply in the tail reaches. In the first situation, optimum irrigation scheduling is a must to avoid wastage and misuse of water. In the second situation, rational water distribution over the available land is necessary so as to apply water at moisture sensitive stages of crop growth and withholding irrigation at the other stages (Reddi and Reddy, 1995). Important components of the crop production equations are crop yield estimates and area estimation. Crop area estimation requires an accurate and reliable method of classification and identification of crops which are grown in the same season (Ajay *et al.,* 1985). Crop water requirement of major crops can be combined with the area of cultivation obtained through satellite data or land use map to compare total water supply and demand in a large area (Menenti *et al*., 1989). Irrigation scheduling based on evapotranspiration values estimated from climatic data is helpful in developing efficient irrigation management practices for different crops, because this approach is relatively simple compared to on site measurements (Menenti *et al*., 1986).

Materials and Methods

Study area is confined to the Balipatna canal command area of Khurda district covering 10 villages of Orissa (20.03^{o} N-20.07^{o} N and 85.53^{o} E – 85.60^{o} E, Fig.1). The area comes within the path 107 and row 58 of IRS P6 satellite. The climate of the area is sub humid with extreme temperature in summer and cool winter seasons. Mean annual rainfall as recorded during the last 20 years (1990-2010) is about 1500 mm. The temperature –rainfall distribution for different months of the area during 2009-10 is given in fig. 2. Crop water requirements of wheat and mustard were determined from meteorological data using Penman-Monteith (FAO, 1993) method (CROPWAT 8.0). FAO expert consultation group recommended Penman-Monteith method (FAO, 1993) for calculating reference evapotranspiration (ET_o) which was used in the model. The input parameters for calculation is monthly maximum and minimum temperatures in ^{o}C, relative humidity in percentage, wind speed in km / day and sunshine hours. For the different meteorological stations in a country, package provides solar radiation (MJ / m^2 / day) based on the elevation above m.s.l., latitude and longitude. Other necessary inputs for ET_o calculation are obtained from the meteorological data for major climatic stations worldwide, which are built in to the program. It estimates crop water requirement (ET_{crop}) through the given equation as $ET_{crop} = ET_o \, . \, K_c$ where, K_c is crop coefficient. CROPWAT calculates irrigation requirement (mm / day and mm / 10 days) by simply subtracting effective rainfall values from the crop water requirement. In the present study, effective rainfall was calculated through USDA Soil Conservation Service method. The input meteorological data were collected from meteorological observatory OUAT, Bhubaneswar. The crop coefficient values for rice and small vegetables namely brinjal and tomato were used from Penman- Monteith tables (FAO, 1993; Table 1& 2) for various crops. Amounts of irrigation (mm) applied to different crop fields were estimated from canal / tube well discharge data for 2009-10 *rabi* season and from the information on the number of times and duration each field was irrigated. Irrigation scheduling efficiencies of small vegetable crops for different soil series were computed from stage wise crop coefficients (FAO, 1993), rooting depth, water depletion level and yield response factors (Table 1&2). The rice crop module requires the following additional information in comparison to non-rice crops for calculating crop water requirements: 1. transplanting date 2. Duration of nursery and land preparation (including puddling) 3. Wet crop coefficients and 4. Puddling depth. Vegetable fields namely brinjal and tomato were divided into four major groups according to number of times each field was irrigated; namely, two times, three times and four times. Under each of these groups, three major irrigation schedules of applications were noted (Table 3). Land use map of the study area (hard copy) for the year 2002-03 was prepared based on detailed field survey. Maximum Likelihood Classified image of IRS-P6 LISSIII

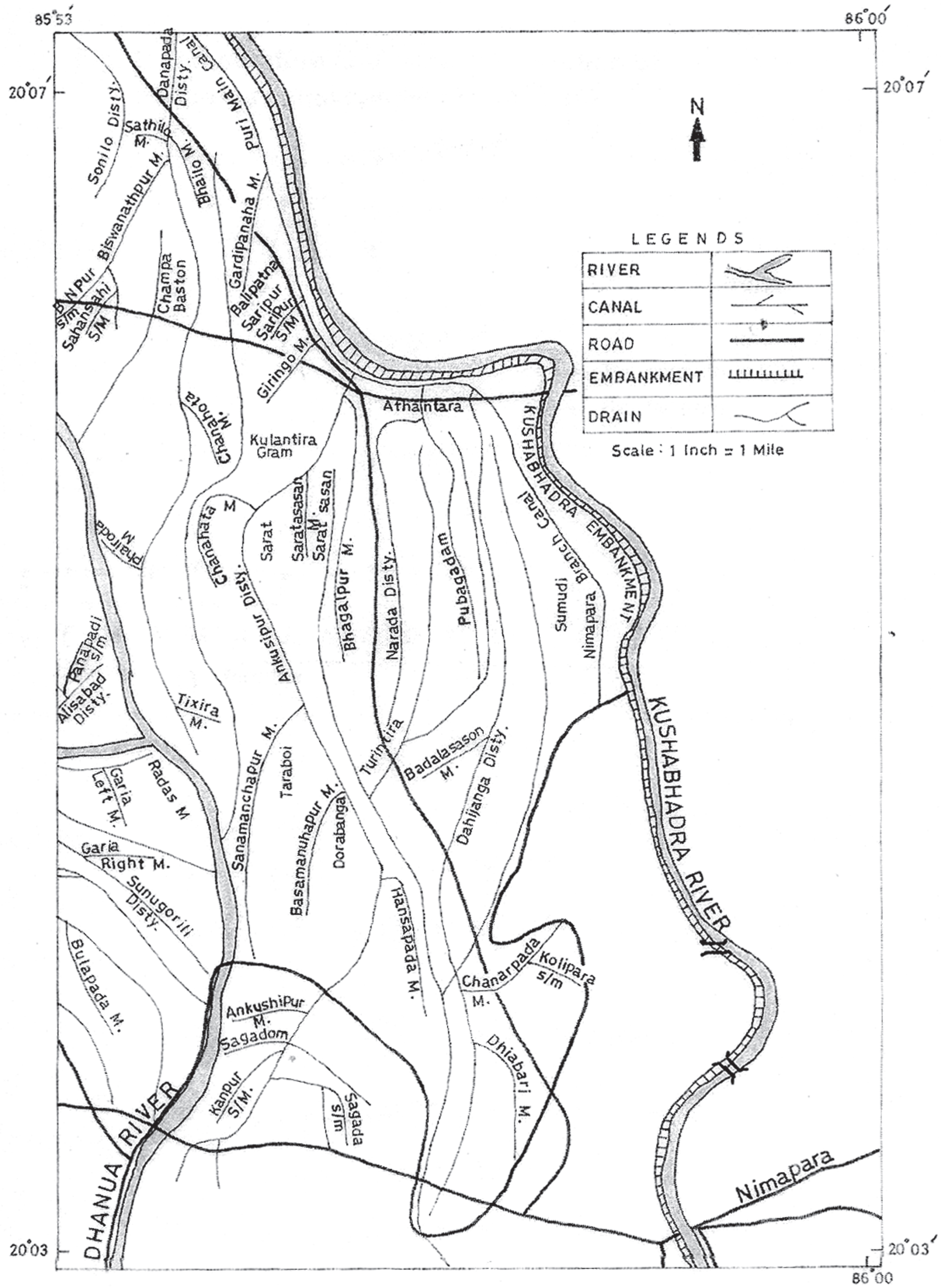

Fig. 1. Balipatna canal command area (Source: Nimapara Irrigation Division, Nimapara)

data and SOI toposheets (1: 50,000) was collected from Orissa Space Application Centre (ORSAC). The DOP of the satellite was 7th Feb., 2003 with a spatial resolution of 23.5 m. The classes like rabi rice and vegetables were visually analysed and separated out from other classes. The map was then taken to the farmer's field of the study area (1st week of Jan., 2010) and verified with the vegetable and rice cultivated fields (10 villages, 3-4 locations in each). Any change in cropping pattern observed between land use map and rabi crop cultivated for the year 2009-10 was noted. Based on the ground truth field verification, the rabi rice and vegetable (brinjal and tomato which were mostly cultivated) cropped areas were redrawn in the final map.

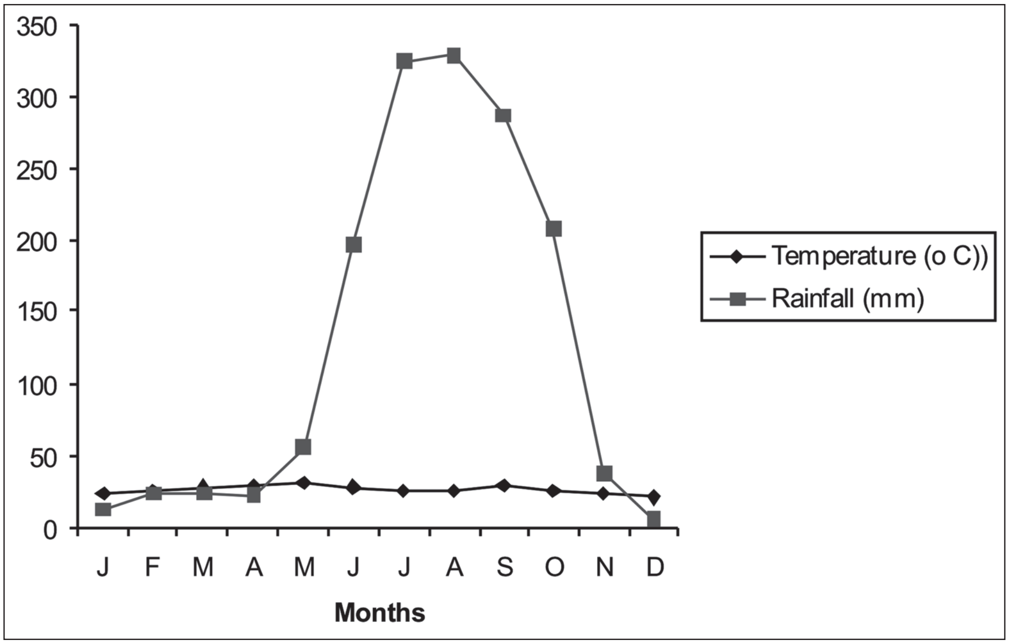

Fig. 2. Temperature and rainfall distribution of Balipatna canal command (2009-10)

Table 1. Crop coefficients, rooting depth, puddling depth, water depletion level and yield response factor of rice

Stage	Nursery	Land preparation		Growth stage				
		Total	Puddling	Initial	Dev.	Mid	Late	Total
Length (days)	30	20	5	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
Crop height (m)	-	-	-	-	-	1.0	-	

→ Coefficients in between initial and mid stages

Table 2. Crop coefficients, rooting depth, water depletion level and yield response factor of small vegetables

Growth stage	Initial	Development	Mid	Late	Total
Length (days)	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
Crop height (m)	-	-	0.45	-	

→ Coefficients in between initial and mid stages

Making use of these field verification maps, the rice and small vegetable areas were separated from other classes such as i) Kharif rice ii) forest plantations iii) built up areas and iv) water bodies. In GIS mode the areas under rice and vegetables were obtained.

Crop water requirements of rice and vegetables were computed from stage wise crop

Table 3. Major irrigation schedules for vegetables followed in the study area

Two irrigation	25,85 / 25,45 / 25,60
Three irrigation	25,55, 95 / 30,60,100 / 25, 45, 95
Four irrigation	20,40,70,100 / 30,45,70,90 / 25,35,55,95

coefficient values, rooting depth, water depletion level, yield response factors (Table 1 and 2) and reference evapo-transpiration data.

Rice cropped fields, numbering over 110, and vegetable field numbering over 75, were randomly chosen in the canal command area, covering soils of the four soil series. Care was exercised in selecting the fields so that these could be easily identified in the land use map. Canal discharge data for different minors in the command were collected from the Irrigation Departments of Balipatna and Bhubaneswar. In some of the fields canal irrigation was also supplemented with tube well water. In such cases the information with regards the type of pump, its capacity, number of hours of run and the number of irrigations given from the tube well were collected from the individual farmers. These were used to calculate tube well supplement of mm water applied in each cropped field. Conveyance losses were considered according to the distance of crop fields from the outlet of the canal / minor. A 70 % application efficiency was arbitrarily taken in cases of irrigation applied from canal and a 100% application efficiency was taken for the fields irrigated through tube well.

Results and Discussion

Verified land use map gave broadly eight classes; namely, Agricultural land-rabi rice, agricultural land-kharif crop, agricultural land-small vegetables, agricultural land-plantation, forest plantation, wastelands and water bodies (Fig. 3). From a total area of 5451 ha in the final map, area under rabi rice and small vegetables were respectively found to be 723 ha and 262 ha.

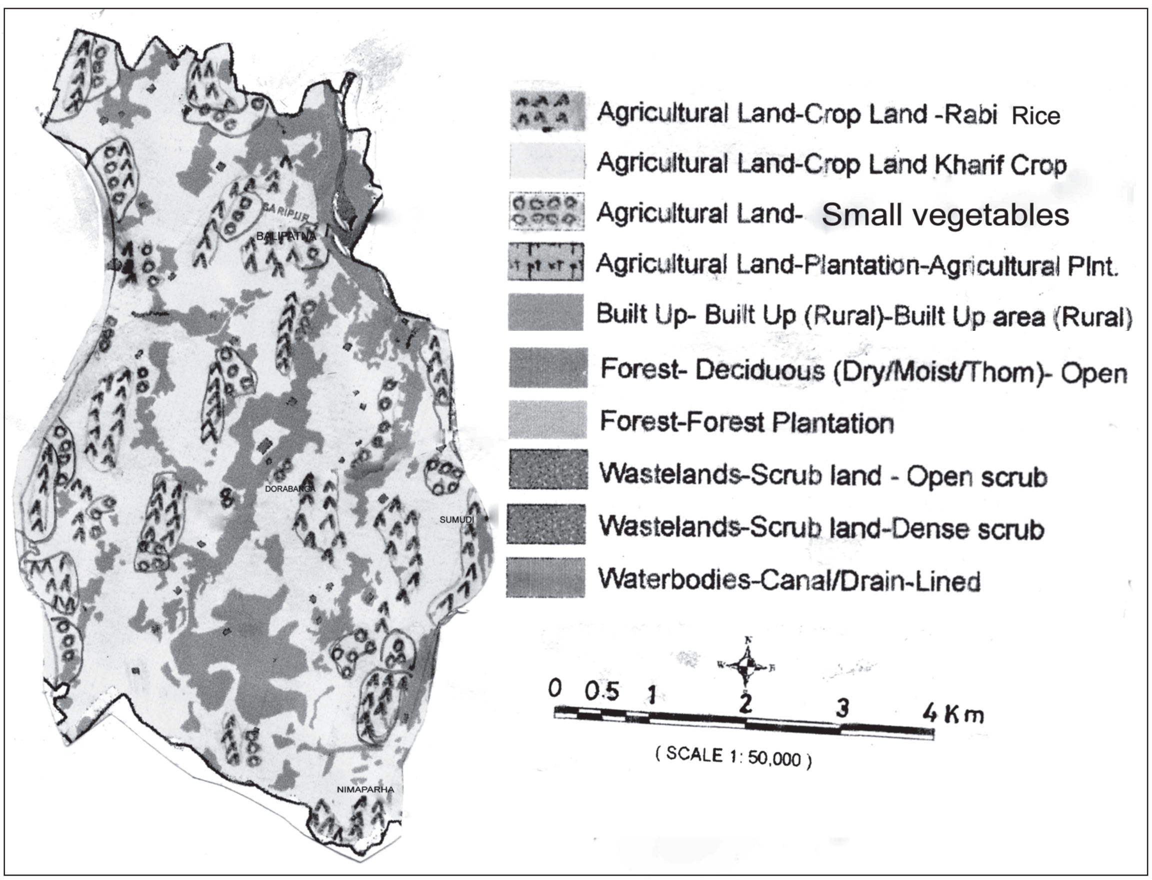

Fig. 3. Land use map of Balipatna canal command (2009-10)

Table 4. Results obtained through agroclimatic data and land use map

Crops	Rice	Vegetables
GIS classified area(ha, 2009-10)	723.0	262.0
Crop water requirements(mm)	757.6	368.1
Effective rainfall(mm)	90.0	116.8
Irrigation requirement(ha-m)	482.7	65.8
Total supply(ha-m, 2009-10)	314.5	48.6
Deficit(ha-m, 2009-10)	168.2	17.2

Average irrigation water requirements which is the difference between crop water requirement and effective rainfall obtained from 2009-10 climate, crop and soil data were 667.6 mm for rice and 271.5 mm for vegetables (Table 4). These data are in agreement with the findings of Panigrahi *et al*. (2006 & 2010) who found that the water requirements of winter rice in the subhumid regions of Orissa (Chiplima, OUAT) were around 600-720mm and the requirements for tomato crop were around 277 to 284 mm and for other vegetables it was around 318 mm (Mishra *et al*., 2009). From the field survey it was found that there was no considerable change in the cropping pattern from the year 2002-03 to 2009-10. The 2009-10 rice and vegetable classes (areas) were merged with irrigation requirements of both the crops. This gave a total irrigation requirement respectively of 482.7 ha-m for rice and 65.8 ha-m for vegetable crops. These values when subtracted from total supply of irrigation water (average depth received by individual fields X area), a deficit of 168.2 ha-m for rice and 17.2 ha-m for vegetables could be worked out (Table 4). Irrigation scheduling efficiencies for vegetables were more for Dorabanga series for all kinds of water applications. Balipatna series performed 2nd to Dorabanga, where as Sumudi and Nimaparha soils performed below the above two soils (Table 5). The available moisture holding capacities (AWC) of Dorabanga and Balipatna soils were higher (220 mm /m and 200mm /m respectively) than for the other two soils (160 and 150 mm / m). This might have resulted in more scheduling efficiencies in earlier soils. The irrigation scheduling efficiencies of three times of applications were higher for all soils as compare to four times of applications. This possibly might have resulted from right amount of applications at critical growth stages (55-60 DAT) in case of three times of application. Where as in case of four time application, the 4th applied irrigation was not so effective in contributing and in bringing high scheduling efficiencies, because vegetables are known to withstand more drought in later stages (Anonymous, 2010). Delay in 1st irrigation by 5-6 days for three time of application resulted in high scheduling efficiencies for all soils as the soil contained enough moisture from rainfall during the month of transplanting (Oct., 20). With the increase in number of irrigations there was a decrease in scheduling efficiencies for all soil groups because more application of irrigation might have resulted in a wastage.

Conclusions

The estimated irrigation requirement values in the present study were close to crop water requirement because of small amount of effective rainfall in the *rabi* season. Combination of verified land cover map derived through Supervised Maxmum Likelihood Classification of satellite data, SOI toposheets and ground truth and agroclimatic data gave irrigation requirement of 482.7 ha-m for rice and 65.8 ha-m for vegetable crops. From a total supply (314.5 ha-m for rice and 48.6 ha-m for vegetables), it was found that there was a net deficit of irrigation water (168.2

Table 5. Best irrigation schedules obtained in CROPWAT 8.0 for different soil series

Irrigation schedules	Schedule efficiency (%)			
Time in DAT	Balipatna	Dorabanga	Sumudi	Nimaparha
25,85	60.0	63.0	59.7	59.7
30,60,100	75.5	78.2	69.6	64.6
20,40,70,100	63.4	65.7	65.1	64.5

DAT: Days After Transplanting

ha-m for rice and 17.2 ha-m for vegetables) for both the crops. While increase in temporal uniformity in irrigation resulted in higher irrigation scheduling efficiencies, any deviation in application from critical growth stages of vegetables resulted in lower efficiencies. Three irrigations with right amount reduced irrigation loss as was observed in case of four irrigation applications. Since in the study area, crop planting or sowing for a particular crop was similar, rate of crop development, length of crop growing season, irrigation after transplanting and climatic conditions did not differ much and therefore the crop coefficient values were taken to be the same for that particular crop for whole command area. Therefore, the variations of irrigation scheduling efficiencies were mainly due to variation of soil physical and fertility factors among different soil series.

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