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Assessment of Watershed Based Water Balance for Irrigation Scheduling through Geospatial Technique

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Abstract

The assessment of water balance for every delineated sub watersheds at its exit involve determination of water availability and demand for various water uses. The Remote sensing data of medium resolution giving level-I details can be utilized for crop group identification and subsequently determine the area under each crop group in the command area of the sub watersheds through use of different crop indices. The crop area of each crop group can then be utilized to estimate the quantity of irrigation water for every crop group. The determination of irrigation frequency for each crop group can be arrived after obtaining the crop and soil parameters in the area. This can then be utilized for arriving at the quantity of irrigation water needed for each crop application as a part of irrigation scheduling measure for each sub watershed in the area. The details of the work are presented in the paper.

Keywords: Irrigation scheduling, Remote sensing, Crop identification, Water balance, Irrigation Water demand, Soil parameters.

INTRODUCTION

Planning of sustainable issues in watershed development such as water balance assessment based on crop water requirement involving spatial data handlingrequires updated information base both at Micro and Macro levels encapsulating wide range of heterogeneous data derived from various sources (12,13,14).

The planning process at the watershed level of suitable size containing level-1 or level-2 information has a requirement of assessing water balance and hydrological evaluation for the watershed (9, 15,16). The assessment of watershed based water balance can give an idea about the water resources supply and demand in the given hydrological planning unit and the amount of conservation that needs to be accordingly carried out at the watershed level (1). The availability of water at the exit of every sub watershed is governed by the rainfall in the area and the demand of water is for various purposes (6,10).

The demand can be for human utilization, crop water requirement, industrial and other water uses. However the irrigation water for crop requirement is one of the major water uses (2, 4). The utility of water for crops will have to be estimated on the basis of simple technique by knowing the crop area and its delta. Subsequently the irrigation frequency can be obtained by knowing the soil parameters such as its bulk density, field capacity and crop evapotranspiration. The crop water requirement is a demand that can be added to other demands for assessment of water balance for every sub watershed in the study area.

STUDY AREA

The study area having 19 ^{0}15’ to 19^0 50’ N and 74 ^{0}17’ to 75^{0}12’ E extent is shown in the figure-1. The Annual Average rainfall of 10 year period = 1200mm, total catchment area = 655.2 Ha with Annual Input due to precipitation being 655.2 x10000 sq m x 1.2 m = 7862400 cubic metre and at the watershed outlet the average annual discharge = 38 litres per sec so the annual runoff volume being (38 x365x24x60x60)/1000= 1200000cubic metre. The loss in the watershed is 6662400cubic metre with runoff coefficient = 0.66 and

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0.79m runoff depth. Table-I gives the annual rainfall values and details of dependability watershed yield for 60 percent risk chosen to design the water conservation structures

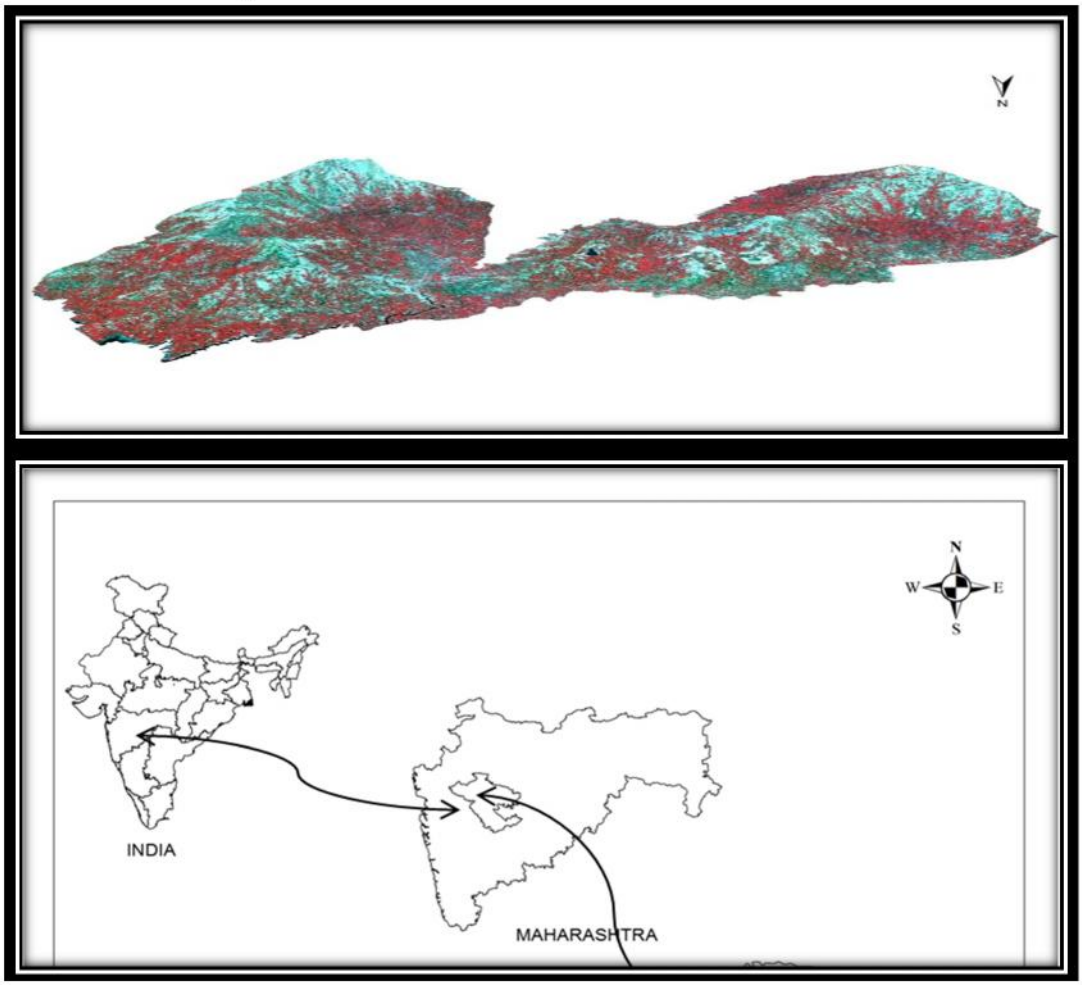

Fig-1 : The study area

TABLE-I:DEPENDABILITY YIELD FOR A WATERSHED

YEAR	**ANNUAL RAINFALL (mm)**	Rainfall Descending Order	**Ranking of Rainfall (m) = (N x P)/100** **N =Number of rainfall records =11.** **P =Risk Percentage (say 60%)** **Then "m" = (11x60)/100** **=6.6 say 6** **The sixth severe rainfall in the catchment is having a depth =842 mm, which is the dependability yield of the catchment.** **Dependability Yield x Catchment Area = Dependability Volume** **=0.842m x 655.2 x1000000 m =551678400cubic metre. Add 10% evaporation loss &15% conveyance loss.** **Water Conservation Structure for the catchment to meet Agriculture requirement should have a capacity less than dependability yield.**
2005	908	1155.2	
2006	598	1077.9	
2007	1077.9	908	
2008	591.5	902.5	
2009	1155.2	869	
2010	778	842	
2011	460	778	
2012	763	763	
2013	842	598	
2014	869	591.5	
2015	902.5	460	

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METHODOLOGY

The estimation of irrigation water for crops in both the seasons is necessary to assess the sub watershed wise crop water requirement for the area. For this purpose the study area has been divided into eight sub-watersheds. The Remote Sensing derived reclassified and colour coded crop indices image was overlaid on the delineated watersheds for evolving crop group area under each sub-watershed. The total water requirement for crops and the depth of Water stored in the Soil up to root zone was obtained using the following equations

Total water requirement for crop type in a watershed (Litres) = Delta of Crops type (m) x Area of the corresponding crop in the watershed (sq-m) x1000 ----(1)

The depth of water stored in the root zone of the crops is given by

$(\gamma \times d \times f)/\omega$ (m) ----------(2)

γ = Bulk density of soil in gm/cm3

d = depth of root zone in cm

f = field capacity of soil

ω = unit weight of water in gm/cm3

The frequency of irrigation for the crop groups was obtained using the equation

(Depth of water in the root zone/Daily Evapo-transpiration) = Frequency of Irrigation ------(3)

Base period of crops/Frequency of Irrigation =Number of water application to cropgroups(N- -----(4)

Total Water Required/N =Water Required for each application-------- ---------(5)

Crop groups in the area was identified by using different crop indices such as Normalized Difference Vegetation Index (NDVI), Perpendicular Vegetation Index (PVI), Ratio Vegetation Index (RVI) and Soil adjusted vegetation index (SAVI) and by formulating the correlation matrices between these indices for different crop groups that needs to be identified.The crop water demand of water in Rabi and Kharif crop periods in the irrigation command of each sub watershed was worked out as a part of water balance assessment.The sub watersheds were delineated using automatic watershed delineation in raster GIS environment.

RESULTS AND DISCUSSION

Table-II gives the different crop parameters in the area covering both Rabi and Kharif cycles. The different parameters considered are root zone depth, delta, base period, crop evapotranspiration, soil bulk density and soil field capacity.

TABLE-II: CROP PARAMETERS IN THE AREA

	Root zone depth (d)(cms)		Delta (cms)	Base period (days)	Bulk density(μ)g/cucm		Evapo- transpiration of crops (cms)		field capacity of soils
crop1	min	max			min	max	Summer	Winter	
sugarcane	20	50	225	365	1.28	1.59	165	160	0.13
maize	20	45	45	90	1.28	1.59	165	160	0.13
crop2									.
wheat	20	35	40	120	1.28	1.59	163	158	0.13
soyabean	30	40	40	100	1.28	1.59	163	157	0.13
bajara	20	30	30	80	1.28	1.59	163	157	0.13
crop3									.
Mug	25	40	30	70	1.28	1.59	158	157	0.13
cotton	25	60	80	180	1.28	1.59	158	157	0.13
Jawar	40	60	45	120	1.28	1.59	158	157	0.13
gram	25	45	30	80	1.28	1.59	158	157	0.13

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TABLE-III: TOTAL IRRIGATION WATER FOR CROP GROUP IN RABI PERIOD

WS no.	Crop type	interval of water application (days)	No. of water application for crop(base period/D)	water depth to be applied for each application(s)	Water Required =Area of the crop*depth of water required for each application	Total Water required for each watershed in TMC
		interval of water application (days)	No. of water application for crop(base period/D)			
1	Crop1	16.0	11.4	0.2	0.02	**0.25**
	Crop2	19.7	6.1	0.06	0.04	
	Crop3	12.7	14.1	0.06	0.18	
2	Crop1	16.0	11.4	0.2	0.04	**0.65**
	Crop2	19.7	6.1	0.06	0.08	
	Crop3	12.7	14.1	0.06	0.53	
3	Crop1	18.2	10.0	0.22	0.06	0.64
	Crop2	22.4	5.4	0.07	0.11	
	Crop3	14.5	12.4	0.06	0.47	
4	Crop1	16.0	11.4	0.2	0.02	0.22
	Crop2	19.7	6.1	0.06	0.04	
	Crop3	12.7	14.1	0.06	0.16	
5	Crop1	16.0	11.4	0.2	0.04	0.44
	Crop2	19.7	6.1	0.06	0.07	
	Crop3	12.7	14.1	0.06	0.33	
6	Crop1	18.8	9.7	0.23	0.03	0.28
	Crop2	23.2	5.2	0.07	0.06	
	Crop3	15.0	12.0	0.06	0.2	
7	Crop1	18.8	9.7	0.23	0.01	0.18
	Crop2	23.2	5.2	0.07	0.02	
	Crop3	15.0	12.0	0.06	0.14	
8	Crop1	18.1	10.0	0.2	0.055	0.6
	Crop2	**22.4**	**5.4**	**0.07**	**0.1**	
	Crop3	**14.5**	**12.4**	**0.06**	**0.45**	

TOTAL =2.77TMC

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TABLE-IV: TOTAL IRRIGATION WATER FOR CROP GROUP IN KHARIF PERIOD

WS no.	Crop type	interval of water application (days)	No. of water application for crop(base period/D)	water depth to be applied for each application(s)	Water Required =Area of the crop*depth of water required for each application	Total Water required for each watershed in TMC
		interval of water application (days)	No. of water application for crop(base period/D)			
1	Crop1	16.0	11.4	0.2	0.02	
	Crop2	19.7	6.1	0.06	0.04	
	Crop3	12.7	14.1	0.06	0.18	0.25
2	Crop1	16.0	11.4	0.2	0.04	
	Crop2	19.7	6.1	0.06	0.08	
	Crop3	12.7	14.1	0.06	0.53	0.65
3	Crop1	18.2	10.0	0.22	0.06	
	Crop2	22.4	5.4	0.07	0.11	
	Crop3	14.5	12.4	0.06	0.47	0.64
4	Crop1	16.0	11.4	0.2	0.02	
	Crop2	19.7	6.1	0.06	0.04	
	Crop3	12.7	14.1	0.06	0.16	0.22
5	Crop1	16.0	11.4	0.2	0.04	
	Crop2	19.7	6.1	0.06	0.07	
	Crop3	12.7	14.1	0.06	0.33	0.44
6	Crop1	18.8	9.7	0.23	0.03	
	Crop2	23.2	5.2	0.07	0.06	
	Crop3	15.0	12.0	0.06	0.2	0.28
7	Crop1	18.8	9.7	0.23	0.01	
	Crop2	23.2	5.2	0.07	0.02	
	Crop3	15.0	12.0	0.06	0.14	0.18
8	Crop1	18.1	10.0	0.2	0.055	
	Crop2	22.4	5.4	0.07	0.1	
	Crop3	14.5	12.4	0.06	0.45	0.6

TOTAL =3.30TMC

Table-III gives the details on the frequency of water application to the crops along with the quantity of water required for each application and total water required during Rabi season, which has worked out to 2.77 TMC. In the same manner Table-IV gives the details on frequency of water application and crop water quantity in Kharif period, which is 3.30 TMC.The irrigation frequency is varying from 14 to 23 days for different crop groups in the sub watersheds. The water availability for each sub watershed can be arrived by utilizing the rainfall and the associated runoff from each sub watershed. The worked out details are presented in Table-V. Both surface and 50% of subsurface water has been considered to arrive at the water availability in each sub watershedIn view of which, it is observed that the geospatial technology has good potential for scheduling of irrigation water as per crop water requirement and to find out the irrigation demand below each sub watersheds in their irrigation command.

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TABLE-V: WATER AVAILABILITY FOR EACH SUB WATERSHEDS

Watershed Number (1)	Area of Watershed (Sq-Km) (2)	Rainfall in (Million Cubic Metre) (3) Column(2) × Depth of Rainfall in m	Runoff in (Million Cubic Metre) (4) Column (3) × Runoff Potential	Column(3) minus Column(4) = Subsurface Flow (Million Cubic Metre) (5)	50% of Column (5) = Water contribution From subsurface For determining Water availability (Million Cubic Metre) (6)	Water availability in the Watershed (Million Cubic Metre) Column(4) +Column(6) (7)
1	205.5	116.37	115.3	1.07	0.54	115.84
2	661.8	372.41	368.9	3.51	1.75	370.65
3	393.6	191.08	188.9	2.18	1.09	190.00
4	255.3	137.03	135.7	1.33	0.67	136.37
5	312.9	156.96	155.3	1.66	0.83	156.13
6	214.6	113.08	111.9	1.18	0.59	112.50
7	240.5	126.51	125.3	1.21	0.60	125.90
8	550.3	269.68	266.8	2.88	1.44	268.24
Total Water availability in the study area of eight watersheds = 1475.63 Million cubic metres						

CONCLUSION: The identification of crop group along with crop area determination using moderate resolution remote sensing images for crops in the command area can be utilized for estimation of irrigation frequency and crop irrigation water requirement after knowing the soil parameters. This can form part of water balance study for the sub watersheds located in irrigation command in which the water availability can be estimated using the past rainfall data in the area. The scheduling of irrigation on the basis of field capacity of soil and its bulk density depends upon the depth of water stored in the root zone of the soil. The water requirements for the crops are generally more for Kharif crop groups due to more depth of root zone.

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