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Micro - Watershed Oriented Approach for Estimation of Irrigation Water in Raigad District, Maharashtra, India

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Introduction

The issues associated with sustainable planning and development of micro-watershed mainly involve assessment of water budgeting. The requirement of water for crop nourishment has a need for utilizing the remotely sensed data to obtain terrain information at micro level and macro level. The analysis also involves usage of other non spatial and spatial secondary data acquired from various sources. (12, 13, 14).

Suitable sized micro-watersheds when seen and interpreted on a moderate resolution remotely sensed data can gives the required details for crop interpretation, which is considered to have value addition in hydrological studies of micro-watersheds (9, 15, 16). The conservation measure can also be evaluated at the watershed level (1). The water contribution of every micro-watershed is dependent upon precipitation in the area of micro watershed and the water demand can be for different purposes (6, 10). The requirement of water for crops in the command area, industrial requirement and other water uses constitute as the demand for water. The water requirement for crops nourishment is a major water utility (2, 4). This crop demand of water therefore will have to be quantified by knowing crop area from remotely sensed data. The delta of crops is also required for getting the volume of water for the entire crop period. The interval at which water is applied to the crops is evolved by knowing parameters of the soil like bulk density, field capacity and evapotranspiration of crops is also required for the purpose.

Study Area

Study area has an extent varying from 18 ^{0}15' to 18^{0} 50' N and 71 ^{0}17' to 73^{0}12' E and the standard False Color composite (FCC) draped on digital elevation model is shown as fig-1. The data pertaining to annual average rainfall of 11 years for the region = 1490.85mm, total catchment area comprising of number of micro-watersheds = 2834.5Km^{2}. Table-I gives the annual rainfall values for the area.

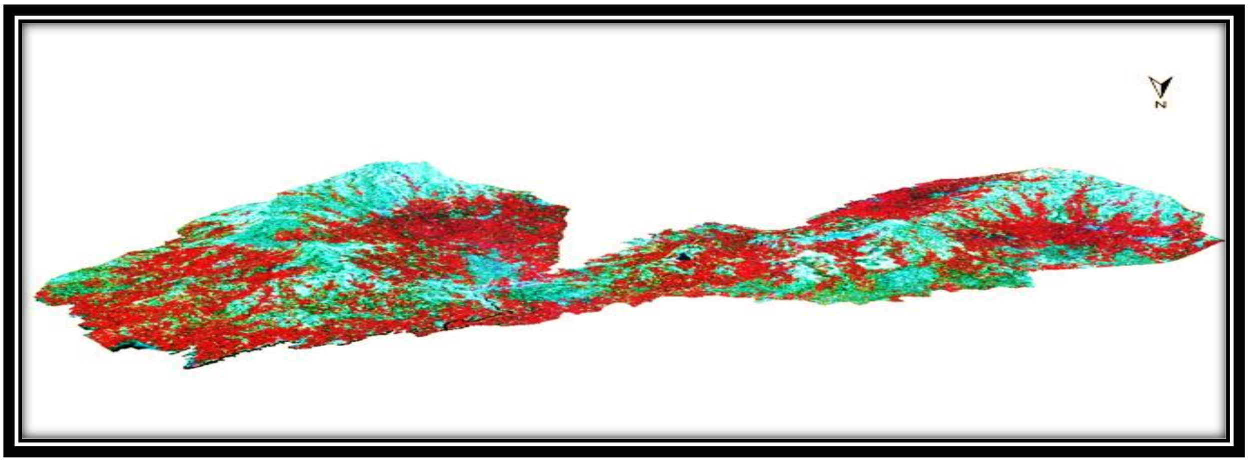

Fig-1: Stand False Color Composite of Study Area

TABLE-I: Annual Precipitation for Study Area

YEAR	ANNUAL RAINFALL (mm)
2005	908
2006	598
2007	1077.9
2008	591.5
2009	1155.2
2010	778
2011	460
2012	763
2013	842
2014	869
2015	902.5

Methods And Process

The crop water quantification during cropping seasons in the micro-watersheds is required for arriving at the interval in which water has to be applied during the crop period. The study area was grouped into eight micro-watersheds and the remotely sensed data utilized to generate re-classified and color coded crop indices images. The color coded crop images was overlaid on the micro watershed boundaries to enable determination of the area under different crops located in the eight sub-watersheds covering the region. The total water for the nourishment of crops during the crop periods is given in the equation-1. The crop indices images for the different vegetation indices were generated for crop interpretation.

Total crop water for every micro-watershed (Litres) = Total depth of water during crop period (m) x Concerned crop area in the sub catchment ---- (1)

Roots associated with different crops are having different depths and the moisture is held in it. The moisture held in the root zone of various crop-types per unit area is represented by equation-2.

$$(\rho_s \times h \times f') / \rho_w \quad \text{-- (2)}$$

ρ_s = Soil bulk density

h = Root zone height

f' = infiltration field rate of soil

ρ_w = density of water

Water depth in the root zone / Daily Consumptive use of crops

= Interval in days for water application to the crops --------------------- **(3)**

Crop Period / Interval in days for water application to the crops =Number of times in a crop period the water will have to be applied------------------ **(4)**

Total Water Requirement for each micro watershed / Number of times in a crop period the water will have to be applied =Water required in litres for every water application in every micro-watershed ---------- **(5)**

Results And Evaluation

The intricate web of agricultural management unfolds through the data encapsulated in Table-II, which meticulously outlines the essential field factors governing the cultivation of diverse crop varieties across both seasonal periods. Delving into the specifics, these factors encompass critical elements such as the depth of the root zone, duration of crop growth, total water requirements throughout the crop cycle, soil bulk density, crop evapotranspiration rates, and the soil's field capacity. Each factor intricately weaves into the fabric of effective water management and crop cultivation, offering a holistic understanding of the agricultural landscape.

Transitioning to Table-III, a detailed narrative emerges, illuminating the precise timing and magnitude of water applications necessary for different crop types during the winter season. This data not only delineates the duration of water application but also quantifies the irrigation water required for each dosing, providing invaluable insights into the optimal irrigation practices essential for fostering robust crop growth. The culmination of these insights culminates in the calculation of the total irrigation water demand for the winter period, meticulously tabulated at 3.38 TMC, thus underlining the imperative of judicious water allocation during this crucial phase of agricultural activity.

Mirroring this meticulous approach, Table-IV offers a comprehensive overview of water management strategies tailored to the demands of the summer season. By meticulously computing the irrigation water requirements for various crop types, this data underscores the necessity of adaptive irrigation practices to mitigate the challenges posed by seasonal variability. With the total irrigation water demand for the summer period estimated at 3.53 TMC, this data serves as a cornerstone for devising effective water allocation strategies, essential for sustaining agricultural productivity amidst climatic fluctuations.

Moreover, the dynamic interplay between water application intervals, spanning from 12 to 22 days across different crop types and sub-catchments, underscores the nuanced approach required to optimize water usage while meeting the diverse needs of crops. This variability highlights the inherent complexity of agricultural water management, necessitating tailored solutions informed by meticulous data analysis. Furthermore, Table-V unveils the intricate relationship between precipitation, runoff depth, and water availability within each micro-watershed. By synthesizing eleven years of annual rainfall records, this data offers a nuanced understanding of natural water availability, essential for informing sustainable water management practices. Through the meticulous calculation of runoff depths based on rainfall intensity and surface runoff coefficients, this data illuminates the hydrological dynamics shaping water availability across different sub-catchments, thus laying the groundwork for informed decision-making in agricultural water management.

In reflection, the convergence of these multifaceted datasets underscores the immense potential inherent in leveraging remotely sensed data to refine water management practices. By harnessing cutting-edge technologies, such as remote sensing, to assess crop water requirements and optimize irrigation scheduling, agricultural stakeholders can unlock new frontiers in water-efficient crop cultivation. This holistic approach not only ensures the judicious allocation of water resources but also fosters sustainable agricultural practices, essential for safeguarding food security and environmental resilience in the face of evolving climatic challenges.

Table-II: Field Factors for Crop Water Application

	Height of Root-zone (d)(cms)		Total Water depth required (cms)	Crop duration (days)	Soil Bulk unit weight (ρ_s) gm/cu-cm		Consumptive Use of crop-types (cms)		infiltration rate of soil strata
Crop-type1	**Min**	**Max**			**Min**	**Max**	**Summer**	**Winter**	
sugarcane	**24**	**52**	**217**	**348**	**1.25**	**1.59**	**165**	**170**	**0.14**
millet	**23**	**46**	**48**	**84**	**1.29**	**1.69**	**167**	**163**	**0.15**
Crop-type2									.
wheat	**23**	**36**	**44**	**112**	**1.28**	**1.43**	**156**	**159**	**0.11**
soyabean	**33**	**42**	**43**	**107**	**1.29**	**1.69**	**166**	**159**	**0.14**
bajara	**22**	**31**	**32**	**85**	**1.39**	**1.69**	**165**	**167**	**0.15**
Crop-type3									.
cotton	**27**	**64**	**82**	**177**	**1.25**	**1.66**	**151**	**156**	**0.14**
Pulses	**28**	**44**	**33**	**84**	**1.39**	**1.69**	**169**	**166**	**0.14**

TABLE-III: WATER APPLICATION FOR CROP TYPES DURING WINTER					
Sub Catchment no.	**Crops**	**Water Frequency (days)**	**Number of times water to be applied for crops**	**Each Application Depth in m**	**Total Water Necessary for crop nourishment (m^3) = crop area***
1	**C1**	**17**	**11.9**	**0.3**	**0.07**
	C2	**20.7**	**6.6**	**0.16**	**0.09**
	C3	**13.7**	**14.6**	**0.16**	**0.23**
2	**C1**	**17**	**11.9**	**0.3**	**0.09**
	C2	**20.7**	**6.6**	**0.16**	**0.13**
	C3	**13.7**	**14.6**	**0.16**	**0.58**
3	**C1**	**19.2**	**10.5**	**0.32**	**0.11**
	C2	**23.4**	**5.9**	**0.17**	**0.16**
	C3	**15.5**	**12.9**	**0.16**	**0.52**
4	**C1**	**17**	**11.9**	**0.3**	**0.07**
	C2	**20.7**	**6.6**	**0.16**	**0.09**
	C3	**13.7**	**14.6**	**0.16**	**0.21**
5	**C1**	**17**	**11.9**	**0.3**	**0.09**
	C2	**20.7**	**6.6**	**0.16**	**0.12**
	C3	**13.7**	**14.6**	**0.16**	**0.38**
6	**C1**	**19.8**	**10.2**	**0.33**	**0.08**
	C2	**24.2**	**5.7**	**0.17**	**0.11**
	C3	**16**	**12.5**	**0.16**	**0.25**
7	**C1**	**19.8**	**10.2**	**0.33**	**0.06**
	C2	**24.2**	**5.7**	**0.17**	**0.07**
	C3	**16**	**12.5**	**0.16**	**0.19**
8	**C1**	**19.1**	**10.5**	**0.3**	**0.105**
	C2	**23.4**	**5.9**	**0.17**	**0.15**
	C3	**15.5**	**12.9**	**0.16**	**0.5**

TABLE-IV: WATER APPLICATION FOR CROP TYPES DURING SUMMER					
Sub Catchment no.	**Crops**	**Water Frequency (days)**	**Number f times water to be applied for crops**	**Each Application Depth in m**	**Total Water Necessary for crop nourishment (m^3)) = crop area* each application depth**
1	C1	16.78	11.9	0.24	0.05
	C2	20.48	6.6	0.1	0.07
	C3	13.48	14.6	0.1	0.21
2	C1	16.78	11.9	0.24	0.07
	C2	20.48	6.6	0.1	0.11
	C3	13.48	14.6	0.1	0.56
3	C1	18.98	10.5	0.26	0.09
	C2	23.18	5.9	0.11	0.14
	C3	15.28	12.9	0.1	0.5
4	C1	16.78	11.9	0.24	0.05
	C2	20.48	6.6	0.1	0.07
	C3	13.48	14.6	0.1	0.19
5	C1	16.78	11.9	0.24	0.07
	C2	20.48	6.6	0.1	0.1
	C3	13.48	14.6	0.1	0.36
6	C1	19.58	10.2	0.27	0.06
	C2	23.98	5.7	0.11	0.09
	C3	15.78	12.5	0.1	0.23
7	C1	19.58	10.2	0.27	0.04
	C2	23.98	5.7	0.11	0.05
	C3	15.78	12.5	0.1	0.17
8	C1	18.88	10.5	0.24	0.085
	C2	23.18	5.9	0.11	0.13
	C3	15.28	12.9	0.1	0.48

TABLE-V: CONTRIBUTION OF WATER FOR EACH MICRO- WATERSHED

Micro-Watershed No (1)	Micro-watershed Area(Km^2) (2)	Rainfall in Million Cubic metre Column-2 x Depth of Rainfall in m (3)	Runoff in Million Cubic metre Column-3 x Runoff Potential (4)	Column-3 Minus Column-4 = Subsurface Flow in Million Cubic Metre (5)	50 % 0f Column-5 = Water Contribution from Sub surface in Million Cubic Metre (6)	Water availability in the Micro-Watershed in Million Cubic Metre (7)
1	205.5	167.07	150.36	16.70	8.35	158.71
2	661.8	538.04	484.23	53.80	26.90	511.14
3	393.6	319.9	287.9	31.9	15.9	303.9
4	255.3	207.55	186.80	20.75	10.37	197.18
5	312.9	254.38	228.94	25.43	12.71	241.66
6	214.6	174.46	157.02	17.44	8.72	165.74
7	240.5	195.52	175.97	19.55	9.77	185.75
8	550.3	447.39	402.65	44.73	22.36	425.02
Total Water contribution in eight micro-watersheds of study area = 2189.2 Million Cubic -metre						

Conclusion:

The interpretation of different crop types using processing of broad band moderate resolution remotely sensed data has contributed to determination of different crop grown area in the two crop seasons for the micro-watersheds. The interval in days in which the water has to be applied to the crops and water quantity for each crop to be applied is possible using the water requirement of crop and the soil parameters such as field capacity of soil, soil bulk density and water depth in the root zone of the soil. This can therefore be expected to form part of water budget assessment at the sub catchment level. The contribution of water from every micro-watershed can be done by using the past annual rainfall records available for the area. The water needed to the crop-types in summer are normally more and that can be attributed to more depth of root zone.

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