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Research Article

COMPARATIVE PERFORMANCE OF DIFFERENT MULTISPECTRAL VEGETATION INDICES FOR DETERMINATION OF CROP COEFFICIENTS OF *RABI* SORGHUM

PIMPALE A.R.[1], WADATKAR S.B.[2], PIMPALE R.A.[3], RAJANKAR P.B.[4] and RAMTEKE I.K.[5]

[1]Section of Agricultural Engineering, College of Agriculture, Nagpur, 440001, Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola, 444 104, India
[2]Department of Irrigation and Drainage Engineering, College of Agricultural Engineering and Technology, Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola, 444 104
[3]Priyadarshini Bhagwati Engineering College, Nagpur, 440022, Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur, 440033, Maharashtra
[4]Maharashtra Remote Sensing Applications Centre, Nagpur, 440010, India
[5]Maharashtra Remote Sensing Applications Centre, Nagpur, 440010, India
*Corresponding Author: Email - arpimpale@gmail.com

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Abstract: For achieving higher water use efficiencies, it is desirable to use each drop of water meticulously. Therefore, precise water management is need of present day. Standard procedure for determination of evapotranspiration of crops has been suggested by FAO 56 publication. Accordingly, irrigation water must be managed. This procedure involves the product of crop coefficients and reference evapotranspiration. These crop coefficients are suggested for standard agronomical conditions. But these may vary according to varying conditions and hence correction factor must be applied. Many research workers have found similarity between the pattern of crop coefficients and multispectral vegetation indices. Therefore, this research work was carried out regarding remote sensing approach for getting quick and accurate estimates of crop coefficients of *rabi* sorghum in *rabi* sorghum growing five districts of Maharashtra. Multidate AWiFS satellite images of the crop growing season were used for extracting the commonly used vegetation indices viz. RVI, NDVI, TNDVI, SAVI and MSAVI2. Ground truth work was also carried out. Profiles of all the five vegetation indices of *rabi* sorghum were studied in detail and compared with profiles of crop coefficients of *rabi* sorghum recommended by MPKV Rahuri. The linear regression was performed between the values of vegetation indices and related crop coefficients. It was found that the vegetation index MSAVI2 have shown comparatively good relationship with crop coefficient of *rabi* sorghum. It is concluded that multispectral vegetation index MSAVI2 can be used as surrogate of crop coefficient of *rabi* sorghum.

Keywords: *rabi* sorghum, Multidate AWiFS satellite images

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Introduction

Considering water scarcity situation in most part of the world, more crop per drop of water is need of present day. For accurate application of irrigation water, it is prerequisite to know precise water requirements of crops. During irrigation it is required to supply water equal to crop evapotraspiration. The most common method to estimate actual crop evapotranspiration (ETc) is given in FAO-56 publication. In this method, evapotranspiration (ETc) is determined as a product of reference evapotranspiration (ETo) and crop coefficient (Kc) which reflects the stage of crop [1, 2]. This can be represented by the equation

$$ETc = ETo \times Kc \quad (1)$$

The parameter ETo is estimated by using standard FAO Penman–Monteith method by using local weather data [1]. Kc values change with the stage of a crop. Kc values of the various crops are to be taken from tables given in FAO-24 publication [3]. These are developed by using lysimeters for the major stages of crop development. These crop coefficients (Kc) are developed for crops grown under optimum agronomic conditions and therefore result in approximate values of the actual ETc and water requirements for a given crop at a given location. These Kc values often lack the flexibility required to capture unusual crop development. It is very often required to make corrections as per local conditions. Therefore, using these traditional crop coefficients for irrigation scheduling can lead to over-irrigation of crops, which can be a serious concern at the field level when irrigation water is in short supply, especially in water-short arid and semi-arid areas of the world [4].

Satellite remote sensing offers a means to overcome some of the shortcomings of traditional Kc curves by providing real-time and/or near real time spatial information on Kc and captures variability among different fields which occurs due to different dates of sowing, soil and field conditions. Many scientists have shown similarity in patterns of Kc and vegetation indices (VI's) suggesting using these VI's as surrogates for crop coefficients. Therefore, present study was carried out to compare the performance of different commonly used vegetation indices with crop coefficients of *rabi* sorghum and find out best vegetation index showing close relation with Kc.

Material and Methods

This study was carried out in five districts of central Maharashtra *i.e*. Pune, Solapur, Ahmednagar, Beed and Osmanabad where the sorghum crop is taken on large scale in *rabi* season. The study area is located between 73°17'19"E to 76°47'42"E longitudes and 19°58'57" N to 17°03'56"N latitudes. Eight multispectral images of satellite IRS- P6, AWiFS (Advanced Wide Field Sensor) of the period of *rabi* season (October / November / December / January / February) of the year 2012-13 were used for this study (path- 097, row-058). AWiFS have 56 m resolution near nadir and 70 m near edge. This study incorporated five vegetation indices *i.e*. Ratio Vegetation Index (RVI) [5], Normalized Difference Vegetation Index (NDVI) [6], Transformed Normalized Difference Vegetation Index (TNDVI) [7], Soil Adjusted Vegetation Index (SAVI), [8] and Modified Soil

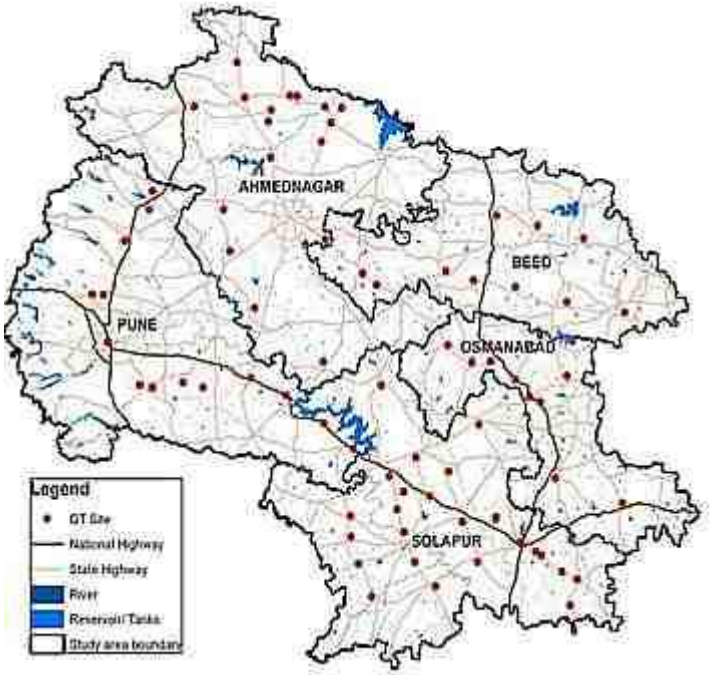

Fig-1 Locations of Ground Truth stations

Adjusted Vegetation Index, 2nd version of MSAVI (MSAVI2) [9]. After geo referencing images and other necessary corrections, the images were processed using ERDAS Imagine software to get the image maps of vegetation indices. Rectangular area of interest (AOI) covering the area of five districts under study was prepared. These images were processed in ERDAS Imagine software by applying image interpreter/spectral enhancement/vegetation indices module to get the images of the five vegetation indices. The stack layer was prepared for each vegetation index. Ground truth activity was carried out on 84 sites of large fields of *rabi* sorghum spread over the study area during 11-15 December 2012. Handheld GPS device, geo tagged camera and a mobile device were used to obtain the locations and elevations of the sites. The information pertaining to date of sowing, variety, soil and probable date of harvesting was obtained from the farmers. The actual stage at the time of ground truth was also decided by referring the criterion suggested by Kansas State University [10] and suggestions by agronomists of the university. The information of other crops such as wheat, maize, sugarcane, pomegranate etc present in the field was also obtained. The ground truth points were plotted as point data layer [Fig-1]. The polygons of *rabi* sorghum and other fields were drawn using ERDAS Imagine and ArcGIS software's. The polygon layer showing pure crop pixels was obtained. By utilizing the AOI, crop polygon layer and VI stack layer, the values of vegetation indices of pure pixels of *rabi* sorghum locations (areas) were obtained for all the eight dates of satellite pass.

Results and discussion

The multidate values of the five vegetation under study were obtained for each ground truth crop polygon. The vegetation indices values of rabi sorghum polygons were classified according to the stage of crop observed during ground truth and the average values obtained are depicted in [Table-1]. It is observed that almost all the vegetation indices show lower values during initial stages of germination and tillering and vegetative growth and reach to their maximum values at 8th or 9th week indicating maximum vegetative growth at booting to anthesis stage. They remain nearly constant and vacillate within a narrow range in 8, 9, and 10th week coinciding mid-season (booting, heading and anthesis) stage. After 11th or 12th week all the VIs shows decreasing trend indicating yellowing and wilting of the plants. After 17th week these VI show lowest values attributing to the formation of black layer on the cobs, bending down of the leaves and gradually becoming dry upto complete senescence. The photosynthetic activity decreases and so the VI show decreasing trend and at later stages values reach below initial.

Table-1 *Average weekly values of the vegetation indices of rabi sorghum*

Week past Sowing	Spectral Vegetation Indices				
	RVI	NDVI	TNDVI	SAVI	MSAVI2
2	1.7917	0.2752	0.8777	0.4070	0.4227
3	1.9176	0.2954	0.8900	0.4406	0.4490
4	2.0753	0.3061	0.9158	0.5102	0.5029
6	1.9418	0.3277	0.9000	0.4665	0.4708
7	2.2433	0.3793	0.9341	0.5604	0.5408
8	2.3325	0.3788	0.9406	0.5793	0.5525
9	2.2831	0.3700	0.9396	0.5757	0.5496
10	2.2963	0.3736	0.9366	0.5677	0.5442
11	2.2798	0.3701	0.9288	0.5461	0.5292
12	2.1102	0.3377	0.9158	0.5103	0.5025
13	2.0351	0.3098	0.9097	0.4920	0.4908
14	1.8982	0.2961	0.8944	0.4508	0.4587
15	1.8870	0.2960	0.8861	0.4310	0.4396
16	1.7659	0.2649	0.8736	0.3975	0.5397
17	1.6261	0.2336	0.8577	0.4647	0.3770
18	1.5687	0.2088	0.8422	0.3221	0.4199
19	1.5000	0.2021	0.8314	0.2890	0.3723
20	1.4739	0.1729	0.8262	0.2751	0.3058

The plots of weeks past sowing versus VI's show the temporal development of VI's. This trend of VI's with growing age of sorghum crop (Vegetaion Indices profiles) is shown by the graphs [Fig-2 a,b,c,d and e].

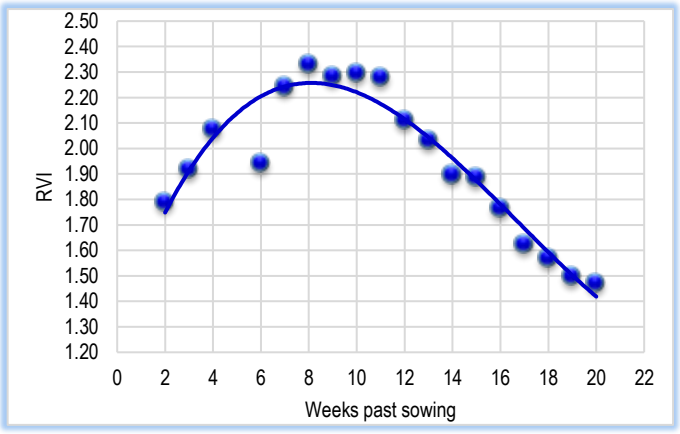

Fig-2a RVI profile of *rabi* sorghum crop

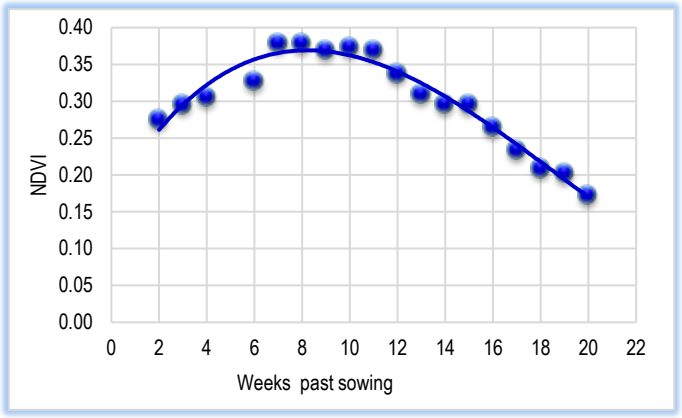

Fig-2b NDVI profile of *rabi* sorghum crop

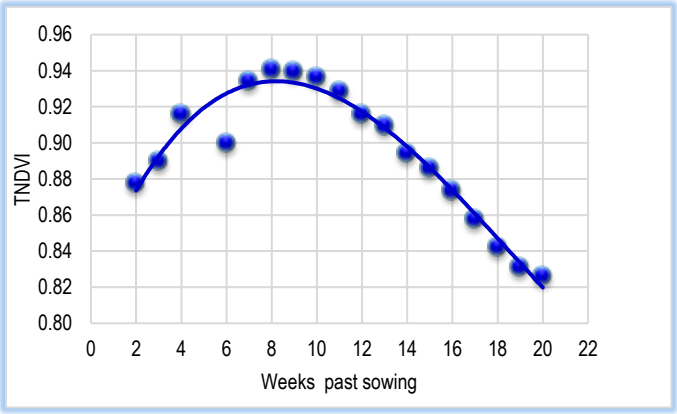

Fig-2c TNDVI profile of *rabi* sorghum crop

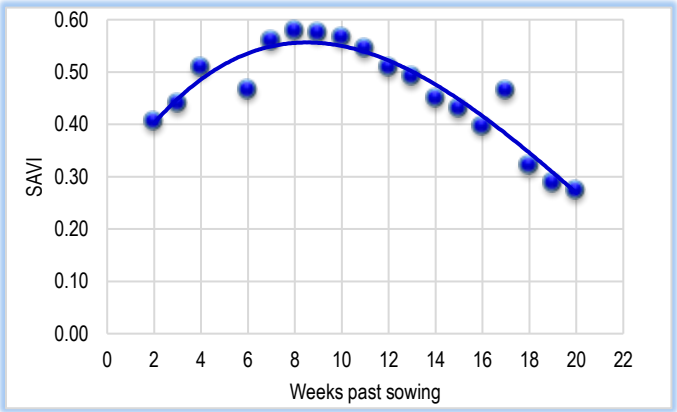

Fig-2d SAVI profile of *rabi* sorghum crop

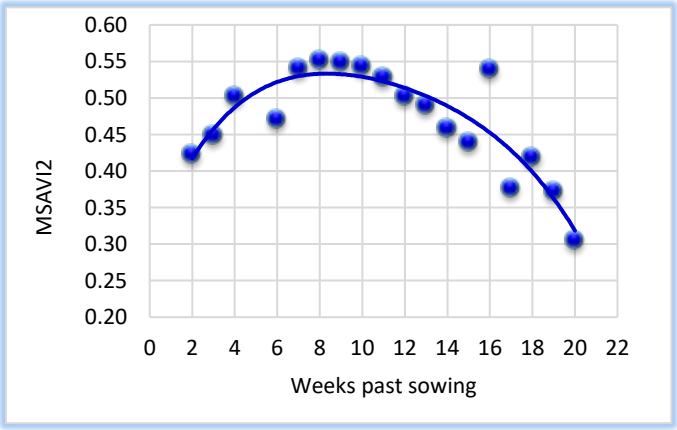

Fig-2e MSAVI2 profile of *rabi* sorghum crop

Fig-2 Profiles of Vegetation Indices of *rabi* sorghum.

The sorghum crop in the study area have generally sparse to medium canopies and do not cover complete ground. This crop is mostly rainfed and grown on residual moisture of preceding monsoon season except few irrigated patches. During the period of study, the rainfall situation in most of the areas was below normal leaving low moisture in the soil. This has resulted in lower values of VIs as compared to normal and/or healthy crop. Similar pattern of crop coefficients representing the growth of crops were observed by Mandal *et. al*. (2007) [11] for sorghum, Singh *et al*. (2013) [12] for cotton and Kamble *et. al*. (2013) [13] for maize and soybeans. The average weekly values of vegetation indices *i.e*. RVI, NDVI, TNDVI, SAVI and MSAVI2 for *rabi* sorghum [Table-1] were plotted against weekly crop coefficients (Kc) recommended by MPKV Rahuri [14]. Simple linear regression analysis was applied to investigate the relationship between these vegetation indices and crop coefficients. It was observed that a strong correlation existed between all the vegetation indices (VIs) and crop coefficient (Kc) of *rabi* sorghum. From the regression analysis linear prediction models were obtained. These prediction models are:

Kc = 0.681RVI - 0.561	R^2 = 0.738	(2)
Kc = 3.120 NDVI - 0.172	R^2 = 0.790	(3)
Kc = 5.362 TNDVI - 4.031	R^2 = 0.782	(4)
Kc = 2.096 SAVI - 0.200	R^2 = 0.784	(5)
Kc = 2.838 MSAVI2 - 0.570	R^2 = 0.805	(6)

It was found that all the vegetation indices (VIs) have reasonably good correlation with sorghum crop coefficients (Kc) with significantly high R^2 values. However, MSAVI2-Kc model showed highest R^2 value followed by NDVI-Kc model with the R^2 values of 0.805 and 0.790 respectively.

Conclusion

The comparison of VIs with Kc throughout the growth period indicated that the trend of development of all the VIs is nearly same as that of crop coefficients. Both VIs and Kc follow the pattern of growth curve. Among the five vegetation indices RVI, NDVI, TNDVI, SAVI and MSAVI2 under study, MSAVI2 was found highly superior for its linear correlation with crop coefficient with highest R^2 and D values of 0.805 and 0.943 respectively. Thus, the developed MSAVI2-Kc model (Kc= 2.838 MSAVI2 - 0.570) can be used for prediction of crop coefficient of *rabi* sorghum. MSAVI2 can be used as a surrogate of crop coefficient of *rabi* sorghum.

Application of research: The developed MSAVI2-Kc model can be used to determine the precise and near real time spatial water requirement of *rabi* sorghum crop. The combination of near real time MSAVI2 data and automatic weather data can be utilized for automation of irrigation system.

Research Category: Agricultural Engineering

Abbreviations:

Kc: Crop coefficient, VI: Vegetation Index,
R^2: Coefficient of determination
D: Willmott index of agreement

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University: Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola, 444 104
Research project name or number: Multispectral vegetation indices-based crop coefficients for irrigation water management.

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area: Five districts of central Maharashtra, Pune, Ahmednagar, Solapur, Beed and Osmanabad

Cultivar / Variety name: *Sorghum Bicolor - Rabi* sorghum

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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