

# Remote Sensing for Recognition and Monitoring of Vegetation Affected by Soil Properties

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## ABSTRACT

Vegetation is an intricate event with large amount of intrinsic spectral, spatial and temporal inconsistency and it is naturally characterized by strapping assimilation in the red wavelengths and towering reflectance in the near infra-red (NIR) wavelengths of the electromagnetic spectrum. The image descriptions generating from various vegetation index like NDVI (Normalized Difference Vegetation Index), NDWI (Normalized Difference Water Index) etc., from multispectral imagery be able to provide exclusive vegetation information about an area. Soil environment circumstances are considerable influence on partial canopy spectra and vegetation index. Consequently, it is significant to monitor the vegetation vitality changes with reverence to the soil background circumstances. The present study an appropriate remote sensing based algorithm, i.e. soil adjusted vegetation index (SAVI) was selected. The investigation of vegetation vigor variations was done for dissimilar time sequence in the part of Andhra Pradesh State, India. The MODIS vegetation index images of 250m resolution are used. NDVI and NDWI images are derivative for red and black soil types and SAVI model was fashioned and executed in ERDAS IMAGINE platform. In SAVI equation, the soil accustomed factor 'L' was personalized with dissimilar values and multivariate SAVI images are derived for both red and black soil regions. In the an assortment of red soil regions, the SAVI with different 'L' values of 0.25, 0.3, 0.4, 0.5 and black soil region, the vegetation envelop is medium and SAVI with 'L' values of 0.3 and 0.4 fashioned fair result on variations of soil and vegetation reflectance over the crop period. The present study was done with the two types of soil regions and with accessible datasets. The psychoanalysis fraction of the study can be extended with multiple data sets and dissimilar seasons.

## INTRODUCTION

Remote sensing is becoming an effective tool in monitoring local, regional and global environmental issues. Remotely sensed data is a proven source of information for detailed characterization of vegetation type, structure and condition (Selvam et al. 2013a-c). Vegetation indices derived from satellite image data become one of the primary information sources for monitoring vegetation conditions and mapping land cover change (Gilabert et al. 2002; Selvam 2016a). The normalized difference vegetation index (NDVI) is one of the most commonly used vegetation index (VI) in global vegetation and change detection studies. NDVI has a high correlation with several vegetation properties, such as amount of green cover, biomass, green leaf area and productivity.

In arid and semi-arid regions, which are characterized by low vegetation cover, the effect of the soil background reflectance needs to be considered (Selvam et al. 2014a-c). Remote sensing techniques sense characteristics of the soil surface. One of remote sensing's most effective capabilities is its ability to monitor variation of diurnal or ephemeral soil properties as they change over time in response to time of day, season, weather and climate. When experimented at regional scale the variations in soil surface moisture, texture, mineral composition, organic carbon etc. can be tracked from week to week for the progression of seasonal patterns of crop growth. The sensitivity of the NDVI to soil back-ground has generated ample interest in developing other indices. Different research groups have developed alternative VI's for qualitative and quantitative evaluation of vegetation characteristics using spectral measurements. Huete et al. (1985) examined the spectral behaviour of a cotton canopy with four soil types alternately inserted underneath at various levels of vegetation density. Steven et al (2003) calibrated various vegetation indices from different sensor systems. The normalized difference vegetation indices (NDVI) from the different instruments was compared. Jiang et al. (2006) analyzed the spatial scale dependencies of NDVI and to analyze the relationship between NDVI results are suggested fractional vegetation cover at different resolutions based on linear spectral mixing models. The results show strong spatial scale dependencies of NDVI over heterogeneous surfaces, indicating that NDVI values at different resolutions may not be comparable. Montandon and Small (2000) studied the impact of soil reflectance on the quantification of the green vegetation fraction from NDVI.

Spectral models and indices are being developed to improve vegetation sensitivity by accounting for atmosphere and soil effects. Huete (1988) presented a new vegetation index known as soil adjusted vegetation index (SAVI). This transformation technique is used to minimize soil brightness influences from spectral vegetation indices involving red and near-infrared (NIR) wavelengths. The SAVI was developed to minimize soil influences on canopy spectra by incorporating a soil adjustment factor L into the denominator of the normalized difference vegetation index (NDVI) equation. For optimal adjustment of the soil effect, however, the L factor should vary inversely with the amount of vegetation present (Qi et al. 1994; Patel et al. 2009; Payero et al. 2003; Sashikkumar et al. 2017; Selvam et al. 2012a and 2015a, b; Singaraja et al. 2016a and b; Zhangyan et al. 2006). Major et al. (1990) derived improved parameters for a SAVI using scattering by arbitrarily inclined leaves (SAIL) model output for simulated wheat canopy reflectance. Huete et al. (2002) evaluated the initial 12 months of vegetation index product availability

from the moderate resolution imaging spectroradiometer (MODIS) on board the earth observing system-Terra platform. Alhammadi and Glenn (2008) detected palm trees health and vegetation greenness change using SAVI. The present study has been undertaken to select a suitable algorithm for assessing the vegetation vigour changes affected by soil properties over space and time and to create a model based on the algorithm with different soil types and finally validating the model with the available soil information.

## STUDY AREA

The present study was carried out in the Deccan part of Andhra Pradesh (AP) state and it lies between 77°40'13" to 80°47'56" E latitude and 16°0'13" to 17°52'56" N longitude (Fig.1) encompassing a geographical area of about 69,693 km<sup>2</sup>. In this semi-arid region, agriculture is the main livelihood activity of the people. The study area consists entire Nalgonda district and major portion of Mahbubnagar, Rangareddy, Medak, Warangal, Khammam and Guntur districts and a small portion of Krishna district. The major cropping season is Kharif season when the region receives about 69% of total annual rainfall (Selvam and Sivasubramanian, 2012a). During Kharif season, the cultivated area is around 17, 97, 000 hectares. Rice, maize and pulses are the important crops.

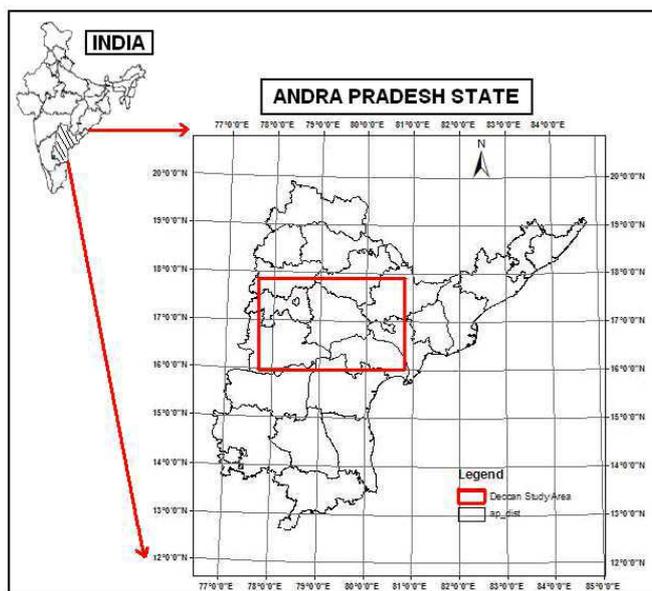


Fig.1. Location map of the study area

## MATERIALS AND METHODS

The moderate resolution imaging spectroradiometer (MODIS) vegetation index images of 250m resolution were used. Red and black soils regions were chosen for analysis and their spreads were digitized in Arc GIS 9.1 environment. The NDVI and NDWI images were derived for those two soil types. The SAVI model was created and executed in ERDAS IMAGINE platform (Selvam et al. 2016b,c) with reference to the NDVI and NDWI values. The SAVI model was validated with the available base soil information map of the study area.

### Data Preparation and Base Soil Information

Data preparation involves with the MODIS data preparation process and the base soil information collection. Base soil map of 1:250,000 scale soil maps generated and published by National Bureau of Soil Survey and Land Use Planning (NBSS & LUP). NBSS & LUP was used to extract the information for the study area where the dependency is up to sub-group level. Two contrasting soil types

were selected i.e., red and black. Multiple polygons for each category were digitized and their boundary was further refined based on image characteristics. All regions have crop cover with varying growth stages.

### Preparation of Different Vegetation Indices Images

The present work is to study the vegetation changes, particularly in agricultural land having different soil backgrounds. For this purpose, different vegetation indices images were prepared. As from the literature, it is very clear that the NDVI, NDWI are the foremost indices for studying the crop characteristics, whereas SAVI gives the information about soil and vegetation reflectances. Hence, NDVI, NDWI and SAVI models were created and executed.

The NDVI images will be generated by the following equation

$$NDVI = \frac{NIR - red}{NIR + red} \quad (1)$$

The NDWI images will be created by the following equation

$$NDWI = \frac{NIR - MIR}{NIR + MIR} \quad (2)$$

The SAVI images will be created by the following equation

$$SAVI = \frac{(1 + L) * (NIR - red)}{NIR + red + L} \quad (3)$$

Where, NIR – near infra-red band wavelength; MIR – middle infra-red band wavelength and L – soil adjusted factor

The SAVI model will be created and executed by changing the L values with different soil backgrounds.

### SAVI Modelling Technique

In this study the SAVI modelling was done by changing the soil adjusted factor 'L' in equation 3 with respect to various red and black soil patches. The study area consists of multiple red soil and black soil. The vegetation density variation in these soil patches were initially monitored by the NDVI images. The canopy moisture status and surface wetness were studied by the NDWI images. From the interpretation of the result, the different 'L' values were assigned and the SAVI model was executed. The SAVI value gives the actual vegetation present in a particular area. It suppressed the soil reflectance in the vegetation mixed environment. The variation value between NDVI and SAVI is the actual soil reflectance value throughout the period. The vegetation density amount was obtained by NDVI images. If the NDVI value is high in an area, then the vegetation is dense. In this situation, the SAVI modeling was executed by assigning low 'L' value and this assumption was obtained by Huete (1988).

## RESULTS AND DISCUSSION

### Generation of Different Vegetation Indices Images on Red Soil Patches

For studying the crop growth over a period it is important to generate different vegetation indices images of a particular period. In this study, red and black soil regions are generated with reference to the initial stage MODIS image. Based on the image characteristics, different red soil region were digitized. The normalized difference vegetation index (NDVI), normalized difference water index (NDWI) and soil adjusted vegetation index (SAVI) images are generated for these red soil regions. All these Vegetation Index images are compared and the variation of vegetation vigour with respect to soil background is carefully studied.

### Generation of NDVI Images

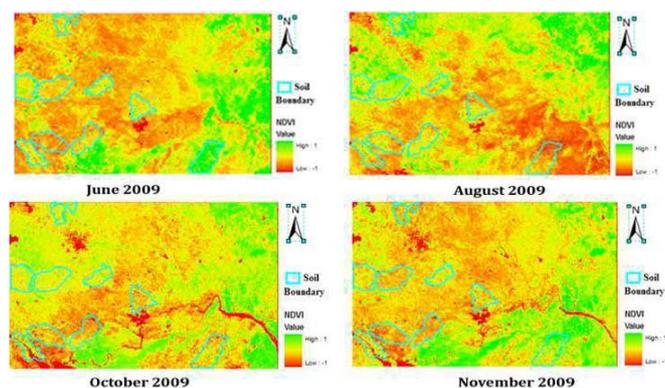
The normalized difference vegetation index (NDVI) is the foremost indicator for studying the vegetation vigour changes. The value ranges from -1 to 1. Water bodies have negative NDVI values, bare soil area have the NDVI values from 0 to 0.2. The vegetation has the NDVI values from 0.2 to 0.8. Low vegetation has low value and dense vegetation area like thick forest have high NDVI value (Huete et al. 1985). The red and NIR (near Infra-Red) bands are required for calculating the NDVI value from the remote sensing data. The NDVI model is executed by using the equation (1). The moderate resolution imaging spectroradiometer (MODIS) sensor has the red and NIR bands as 250 m resolution. Using these two bands the NDVI images were created by using ERDAS 2010 version. After executing the model, the NDVI values for red soil region were delineated. The value shows that these regions have more than 30% canopy cover from initial stage to the final stage of Kharif season. At the middle period the value is touched to peak one. From the observations of NDVI values it is concluded that the red soil area have high vegetation. The NDVI values for red soil region are shown in Table 1 and the NDVI variation images are shown in Fig 2.

### Generation of NDWI Images

The normalized difference water index (NDWI) images were prepared with near infra-red (NIR) and middle infra-red (MIR) bands. The model was executed by using the equation (2). The NDWI gives the information about the vegetation and soil moisture status. The wetness variation over a period was clearly monitored by the NDWI values. It is also an indicator for the canopy wet condition. Here, the NDWI model was successfully executed and its variation was carefully studied. The NDWI values in red soil polygon gradually increases over the Kharif season. While the NDVI value gets reduced, but the NDWI values do not go down. From this observation it is

**Table 1.** Different Vegetation Indices values for Red soil batches

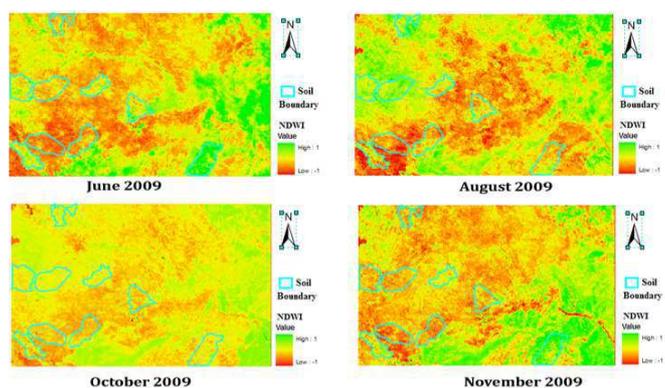
Dates	NDVI	NDWI	SAVI (L=0.2)	SAVI (L=0.3)	SAVI (L=0.4)	SAVI (L=0.5)
1-Jun-09	0.326	0.081	0.196	0.212	0.2285	0.245
15-Jun-09	0.399	0.156	0.2395	0.2595	0.2795	0.2995
1-Jul-09	0.331	0.146	0.1985	0.215	0.2315	0.248
15-Jul-09	0.317	0.152	0.19	0.206	0.222	0.238
15-Aug-09	0.365	0.268	0.219	0.2375	0.2555	0.274
1-Sep-09	0.536	0.335	0.322	0.3965	0.3755	0.402
15-Sep-09	0.551	0.348	0.3305	0.358	0.3855	0.413
1-Oct-09	0.61	0.395	0.3385	0.367	0.395	0.4235
15-Oct-09	0.538	0.309	0.323	0.35	0.377	0.4035
1-Nov-09	0.493	0.282	0.296	0.3205	0.345	0.3695
15-Nov-09	0.51	0.28	0.306	0.3315	0.357	0.3825



**Fig.2.** Different NDVI images on Red soil Patches

**Table 2.** Different Vegetation Indices values for Black soil batches

Dates	NDVI	NDWI	SAVI (L=0.2)	SAVI (L=0.3)	SAVI (L=0.4)	SAVI (L=0.5)
1-Jun-09	0.278	0.042	0.167	0.181	0.195	0.209
15-Jun-09	0.332	0.098	0.1995	0.216	0.2325	0.25
1-Jul-09	0.28	0.118	0.172	0.1865	0.201	0.26
15-Jul-09	0.287	0.11	0.1725	0.1865	0.2	0.2655
15-Aug-09	0.306	0.241	0.184	0.199	0.2145	0.23
1-Sep-09	0.489	0.275	0.293	0.3175	0.342	0.3665
15-Sep-09	0.491	0.317	0.3115	0.337	0.363	0.389
1-Oct-09	0.52	0.32	0.35	0.379	0.359	0.4025
15-Oct-09	0.511	0.348	0.3425	0.371	0.34	0.4
1-Nov-09	0.505	0.347	0.3345	0.3625	0.345	0.389
15-Nov-09	0.513	0.341	0.34	0.37	0.34	0.4

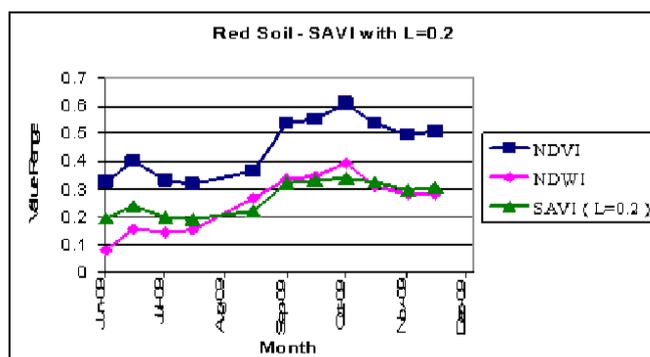


**Fig.3.** Different NDWI images on red soil patches.

concluded that the red moisture holding capacity of the soil is high. At the final stage of the Kharif season the NDWI values are decreased linearly. During this period the agricultural activities are complete, so there is no crop presented. Also the wetness condition of the area is less. This reflects the NDWI variation. The NDWI values for red soil region are shown in Table 2 and the NDWI variation images are shown in Fig 3.

### Generation of SAVI images with different 'L' values

The SAVI model was executed by assigning 'L' as 0.2. This value is the lowest 'L' value for SAVI model creation. The variation between NDVI and SAVI values is plotted in Fig. 4 and SAVI images was shown in Fig 5. From the NDVI and NDWI values, it is concluded that the red region have high vegetation cover. Hence, this low 'L' value is well suited for SAVI modeling. The difference between NDVI and SAVI images gives the soil reflectance values. At the initial stage of the Kharif season, NDVI and SAVI values are equally changing.



**Fig.4.** NDVI, NDWI and SAVI (L=0.2) variations over time on Red soil patches

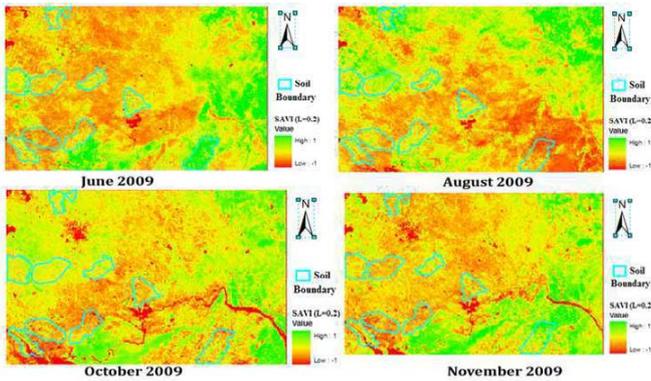


Fig.5. Various SAVI images with L=0.2 on Red soil Patches

But at the middle and the last stage the NDVI values is high, whereas SAVI value is medium. This variation is due to the increase in canopy density on the red soil region. If the vegetation pattern increases, then the soil reflectance decreases. This is reflected in the Fig 4. The SAVI model was executed by changing the 'L' value as 0.3 in equation (3). The variation graph between NDVI and SAVI values was shown in Fig 6 and the SAVI images were presented in Fig 7. The variation is identical in the initial and middle stage of the Kharif season. But the slight difference occurs in the end stage of the season. At this period the soil reflectance was not received due to the dense canopy. Therefore, the SAVI values automatically get decreased at the final crop stage. The SAVI model was executed by assigning 'L' as 0.4. This value is close to the medium 'L' value for SAVI model creation. The variation between NDVI and SAVI values is plotted in Fig. 8 and SAVI images was shown in Fig 9. Here, there is no considerable variation occurred between the NDVI and SAVI values. Hence this 'L' value is not good for the red soil polygon studies. The SAVI model was executed by assigning 'L' as 0.5. This value is the exact middle 'L' value for SAVI model creation. The variation between NDVI and

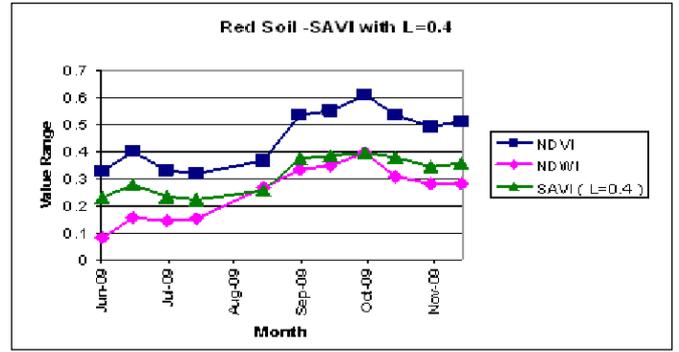


Fig.8. NDVI, NDWI and SAVI (L=0.4) variations over time on Red soil patches.

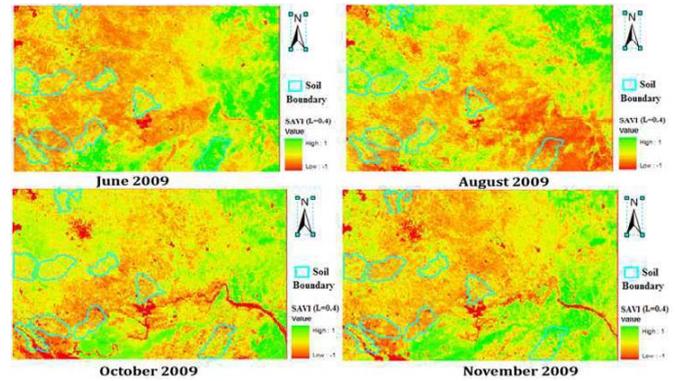


Fig.9. Various SAVI images with L=0.4 on Red soil Patches

SAVI values is plotted in Fig. 10 and SAVI images are shown in Fig. 11. The NDVI value for red soil polygon is high throughout the study period. Therefore, there is no considerable variation occurred between NDVI and SAVI, by giving the high 'L' values for SAVI model execution.

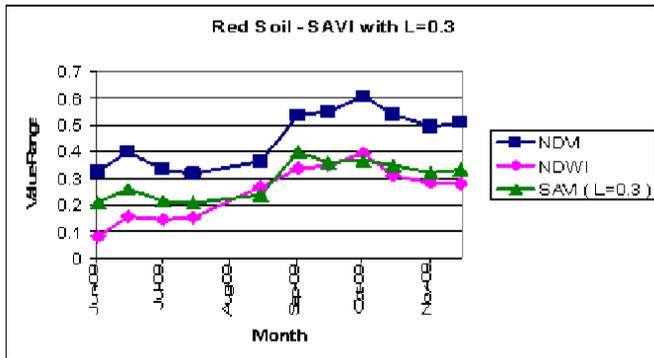


Fig.6. NDVI, NDWI and SAVI (L=0.3) variations over time on Red soil patches.

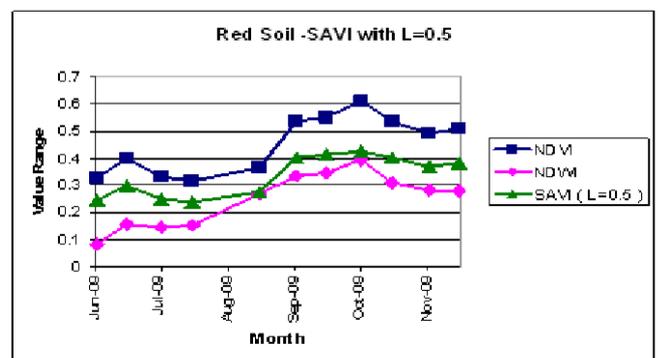


Fig.10. NDVI, NDWI and SAVI (L=0.5) variations over time on Red soil patches

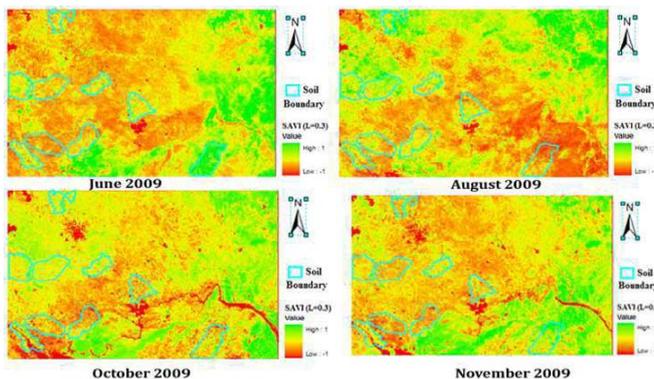


Fig.7. Various SAVI images with L=0.3 on Red soil Patches

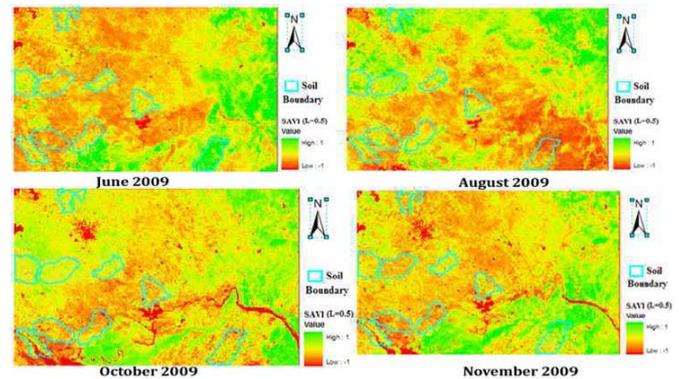


Fig.11. Various SAVI images with L=0.5 on Red soil Patches

### Generation of different Vegetation Indices Images on Black Soil Patches

In this study, black soil region are generated with reference to the initial stage MODIS image. Based on the image characteristics, different black soil region were digitized and their boundary was adjusted. The normalized difference vegetation index (NDVI), normalized difference water index (NDWI) and soil adjusted vegetation index (SAVI) images are derived for these black soil regions. All these VI's images are compared and the variation of vegetation vigour with respect to soil background is carefully studied.

### Generation of NDVI Images

The red and NIR (near Infra-Red) bands are required for calculating the NDVI value from the remote sensing data. The NDVI model was executed by using the equation (1). The moderate resolution imaging spectroradiometer (MODIS) sensor has the red and NIR bands as 250 m resolution. Using these two bands the NDVI images were created by using ERDAS 2010 version. After executing the model, the NDVI values for black soil region were delineated. The value shows that these regions have below 30% canopy cover at the initial stage of the Kharif season and slowly get increased. At the middle period the value touched the peak. From the observations of NDVI values it is concluded that the red soil area have intermediate vegetation. The NDVI values for black soil region are shown in Table 2 and the NDVI variation images are shown in Fig 12.

### Generation of NDWI images

The normalized difference water index (NDWI) images were prepared with near infra-red (NIR) and middle infra-red (MIR) bands. The model was executed by using the equation (2). The NDWI gives the information about the vegetation and soil moisture status. The NDWI values in black soil polygon are gradually increased over the Kharif season. Here the NDVI and NDWI variations are comparably same. From this observation it is concluded that the

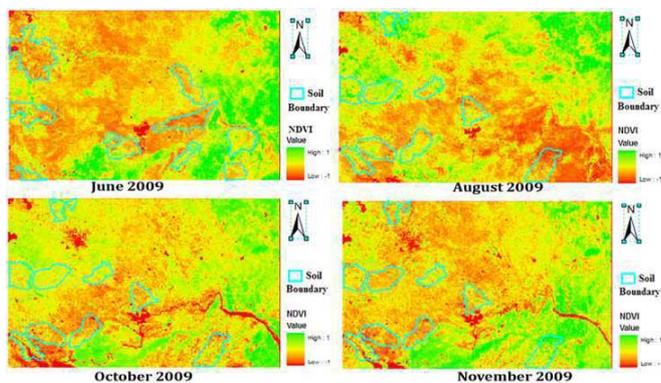


Fig.12. Different NDVI images on Black soil Patches

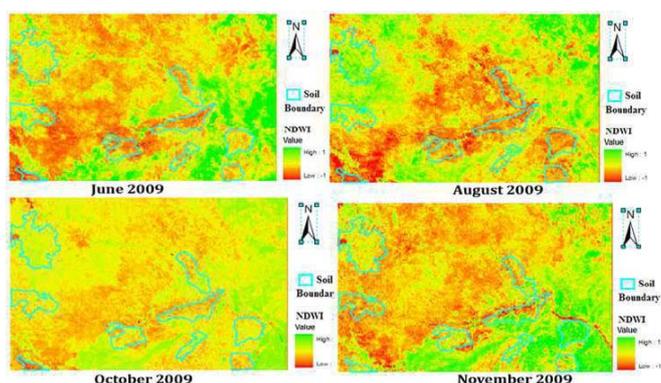


Fig.13. Different NDWI images on Black soil Patches

Table 3. Selection of Suitable 'L' values for Red and Black soil regions

Sl. No.	Soil Regions	Soil Types	Suitable L value
1.	Red Soil Regions	Typic Paleustalfs	0.25
2.		Typic Rhodustalfs	0.3
3.		Typic Haplustalfs	0.4
4.		Rhodic Paleustalfs	0.4
5.		Kandic Paleustalfs	0.5
6.	Black Soil Regions	Endic Haplusterts	0.3
7.		Chromic Haplusterts	0.4
8.		Typic Haplusterts	0.4

NDWI variation of black soil polygon is entirely different, when compared to red soil region. Therefore the moisture status of the black soil patches is also low. The NDWI values are as shown in Table 3 and the NDWI variation images are shown in Fig 13.

### Generation of SAVI images with different 'L' values

The SAVI model was executed by assigning 'L' as 0.2. The variation between NDVI and SAVI values is plotted in Fig. 14 and SAVI images is shown in Fig 15. From the NDVI value, it is concluded that the black region have intermediate vegetation cover. Hence, this low 'L' value is not giving the correct variation for soil and vegetation reflectance. There is no considerable variation for NDVI and SAVI. The SAVI model was executed by changing the 'L' value as 0.3 in the equation (3). The variation graph between NDVI and SAVI values is shown in Fig 16 and the SAVI images are presented in Fig 17. The variation is identical at the initial stage of the Kharif season. But a slight difference occurred in the end stage of the season. The variation between SAVI and NDVI images was slightly increased by increasing the 'L' value. The SAVI model was executed by assigning 'L' as 0.4. This value is close to the intermediate 'L' value for SAVI model creation. The variation between NDVI and SAVI values is plotted in Fig. 18 and SAVI images are shown in Fig 19. The black soil regions

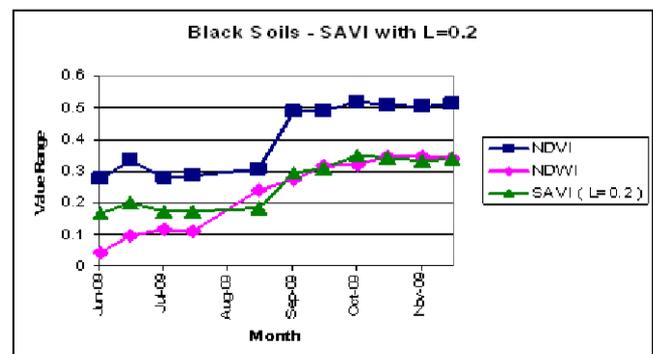


Fig.14. NDVI, NDWI and SAVI (L=0.2) variations over time on Black soil Patches

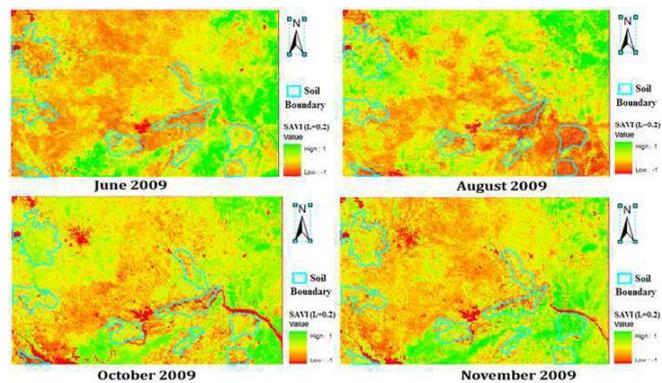


Fig.15. Various SAVI images with L=0.2 on Black soil Patches

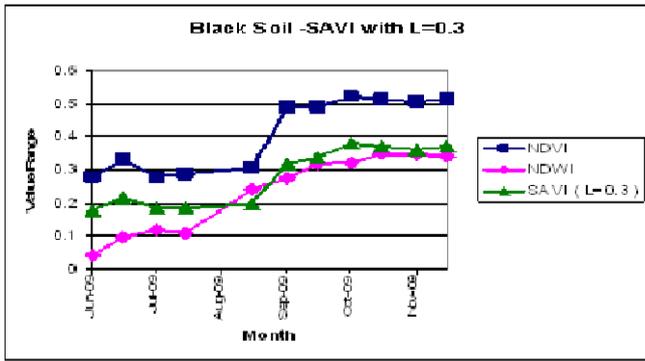


Fig.16. NDVI, NDWI and SAVI (L=0.3) variations over time on Black soil Patches.

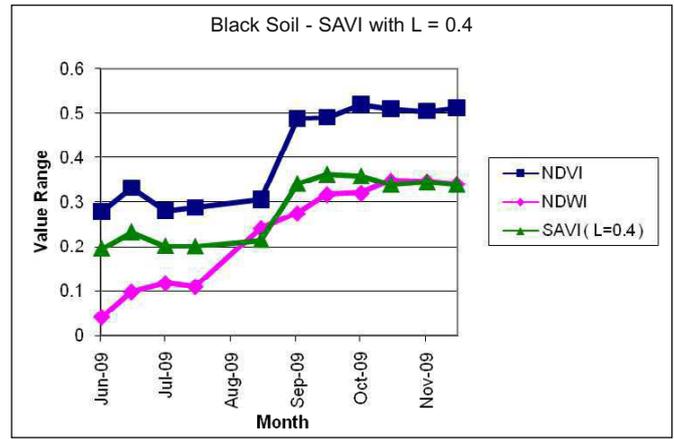


Fig.18. NDVI, NDWI and SAVI (L=0.4) variations over time on Black soil Patches.

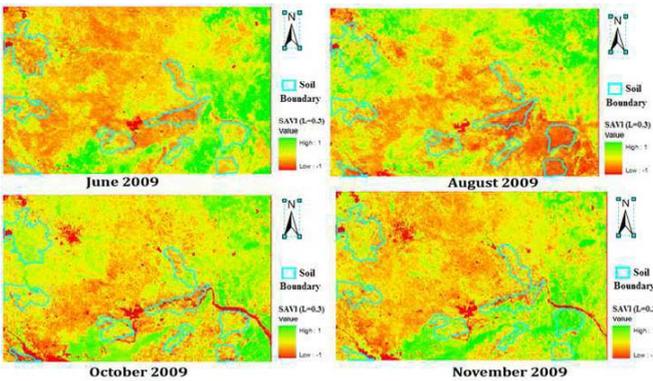


Fig.17. Various SAVI images with L=0.3 on Black soil Patches.

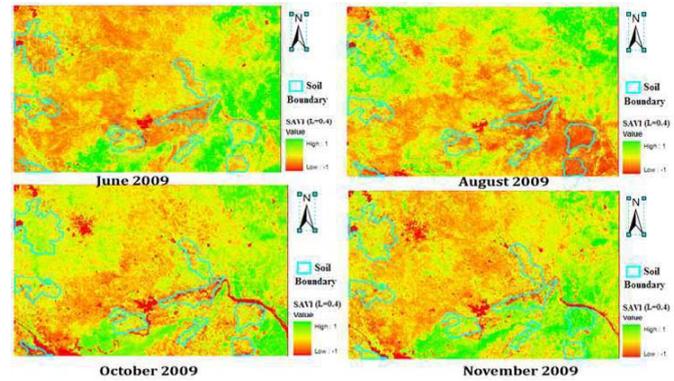


Fig.19. Various SAVI images with L=0.4 on Black soil Patches.

have medium NDVI values; therefore the intermediate 'L' value gives better variation between NDVI and SAVI images. The NDVI value becomes high in the final stage of Kharif season. At this period the soil reflectance was not received due to increase in canopy. Therefore, the SAVI values automatically get decreased at the final crop stage. The SAVI model was executed by assigning 'L' as 0.5. This value is the exact intermediate 'L' value for SAVI model creation. The variation between NDVI and SAVI values is plotted in Fig. 20 and SAVI images was shown in Fig 21. The variation between NDVI and SAVI values is slightly get reduced by changing the 'L' value from 0.4 to 0.5

**CONCLUSIONS**

The various vegetation index images from MODIS data over the study area were carefully analyzed. The vegetation density variation obtained from the NDVI and NDWI values were analyzed in the study area. The areas with high vegetation density have low 'L' value. Based on this principle the 'L' value was decided and SAVI model was executed with multiple 'L' factor for red and black soil regions. The different 'L' values are 0.2, 0.3, 0.4 and 0.5. The red soil region has high vegetation cover when compared to the black soil patches; therefore, the NDVI value is also high. The low 'L' value gives better NDVI and SAVI variation. The SAVI value with soil adjusted factor 'L' as 0.2 and 0.3 has given the better variation between the SAVI and NDVI values. All other SAVI models have the low variation. High variation was obtained between SAVI and NDVI when the value of 'L' was 0.2 when compared to the image obtained for 'L' value as 0.3. Hence it is concluded that the SAVI model with 'L' as 0.2 gives better result and was recommended for red soil regions. In black soil region, the vegetation cover is intermediate, therefore the NDVI is medium. The intermediate 'L' value gives better NDVI and SAVI variation. The SAVI value with soil adjusted factor 'L' as 0.4 and 0.5 gave the better variation between the SAVI and NDVI values for black soil

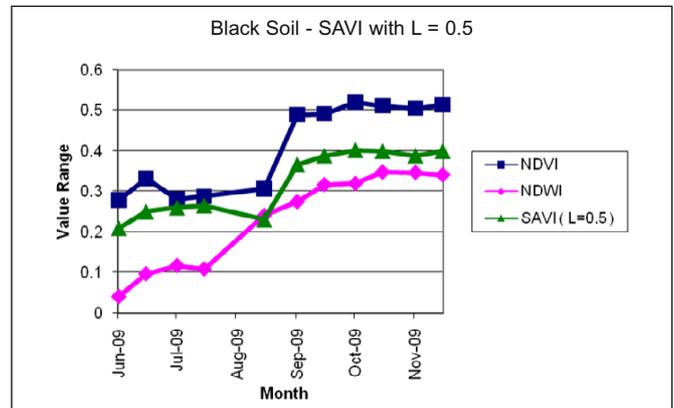


Fig.20. NDVI, NDWI and SAVI (L=0.5) variations over time on Black soil Patches.

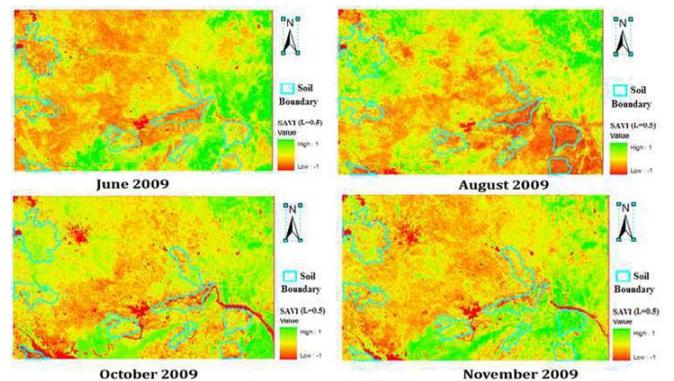


Fig.21. Various SAVI images with L=0.5 on Black soil Patches.

regions. High variation was obtained between SAVI and NDVI when the value of 'L' was 0.4 when compared to the image obtained for 'L' value as 0.5. Therefore, it is concluded that the SAVI model with 'L' value as 0.4 is suited for black soil region. Based on the SAVI modeling technique, it was concluded that the vegetation growth and its density variation was plausibly high on the red soil region than the black soil region. This study was carried out with two types of soil regions and available datasets. The SAVI model with different 'L' values can be applied other soil types. The study can be extended with multiple data sets for different seasons.

*Acknowledgements:* Authors are grateful to Shri A.P.C.V. Chockalingam, Secretary and Dr. C. Veerabahu, Principal, V.O.C College, Tuticorin for his support to carry out study.

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(Received: 15 December 2016; Revised form accepted: 17 April 2017)

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