

Application of Distance Based Vegetation index For Agricultural Crops Discrimination

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ABSTRACT:

Among several vegetation indices, NDVI is the most extensively used index because of its ratioing properties and as it is simple to compute. But its usefulness in discriminating vegetation types with high cover density or high LAI (for example opium poppy and winter wheat) is limited due to saturation of NDVI values, insensitivity at high LAI's and variations in canopy density, resulting in confusion between crops like those mentioned above. Due to these limitations discriminating between poppy and wheat using NDVI is a problem. Weighted Difference Vegetation Index (WDVI) counters these limitations effectively by enhancing canopy reflectance component. The application of WDVI is observed to maximize the separation between winter wheat and opium poppy. The developed method is applied on IRS-1D LISS-III data sets covering parts of Madhya Pradesh and Rajasthan, India. For operational use of this index, interactive identification of soil pixels is tedious and error prone. To circumvent this difficulty authors propose a method for automatic extraction of soil and vegetation pixels using two date multispectral data (acquired during fallow and crop season). For automatic extraction of soil and vegetation pixels a modified version of WDVI, called as Inverse WDVI (IWDVI), termed as corrected red, is proposed. Advantages of this procedure are automatic identification of soil and crop land pixels.

1. INTRODUCTION

Opium poppy crop is cultivated in quite a few countries all over the world. The major opium producing countries are in Asia. In India legal cultivation of opium poppy takes place in Madhya Pradesh, Rajasthan and Uttar Pradesh under the supervision of Government of India officials. Ground surveys are conducted from time to time during the crop season to monitor cultivation activity. Remote sensing technology provides an alternative to expensive, time consuming ground surveys and also offers an opportunity for independent validation of crop acreage. Medium to high spatial resolution multispectral data provided by remote sensing satellites, like, IRS-1C/1D LISS-III to recently launched IRS-P6 (sensor details onboard these satellites are shown in TABLE.1) are useful to monitor the crop. Crop acreage estimates at range level (comprising of eight to ten villages) and under certain conditions at village level with reasonable accuracy can be obtained using medium spatial resolution multi spectral data like IRS-1C/1D LISS-III. For cultivator level information one needs to use IRS-P6 LISS-IV data or any other multi spectral data having comparable spatial resolution. The multispectral bands provide useful spectral contrast among several terrain features, which can be exploited by employing digital image processing techniques.

Satellite	Sensor	Spectral bands	Spatial Resolution (mt)	Swath (km)	Revisit
IRS-1C/1D ^[1]	LISS-III	Green	23.5	141	24
		Red	70		
		Near IR			
		Middle IR			
	WiFS	Red	188	810	3
		Near IR			
IRS-P6 ^[2]	LISS-IV	Green	5.8	23.5	5
		Red			
		Near IR			
	LISS-III	Green	23.5	141	24
		Red			
		Near IR			
		Middle IR			
	AwIFS	Green	56	>700	5
		Red			
		Near IR			
		Middle IR			

Table I. Sensor characteristics

GREEN (0.52 μ m – 0.59 μ m), RED (0.62 μ m – 0.68 μ m), Near Infra red (0.77 μ m – 0.86 μ m), Middle IR (1.55 μ m – 1.70 μ m)

2. CROP CALENDAR AND GEOGRAPHIC AREA

Information regarding crop calendar for a given geographic area is important as it helps in identifying period of peak vegetative cover for crop of interest and status of competing crops during that time. This type of information is vital in selecting appropriate image data sets. Opium poppy crop in Madhya Pradesh and Rajasthan is sown during October/November, flowering takes place around January end and lasts for about seven to ten days.

Lancing (process of extracting opium gum) generally begins during first week of March and about four lancements are carried out during a period of 15 to 20 days. If license is issued late, sowing can happen as late as first week of December and yield in this case will be low due to reduced number of lancements. Ground water is the major source of irrigation in this area. In the fields adjacent to poppy other crops like wheat, garlic, onion, vegetables, mustard, pulses

(bengal gram), isabgol are sown. Crop calendar for opium poppy is shown in Fig.1.

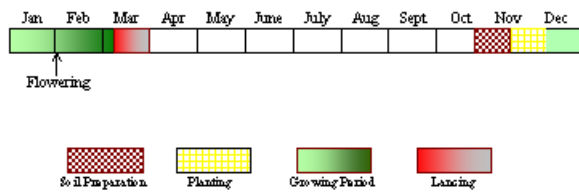


Figure 1 : Crop Calendar of Opium Poppy
The study area is western part Mandsaur District of Madhya Pradesh and soil in this area is black with high clay content. Geographic location of the district is shown in Fig.2.

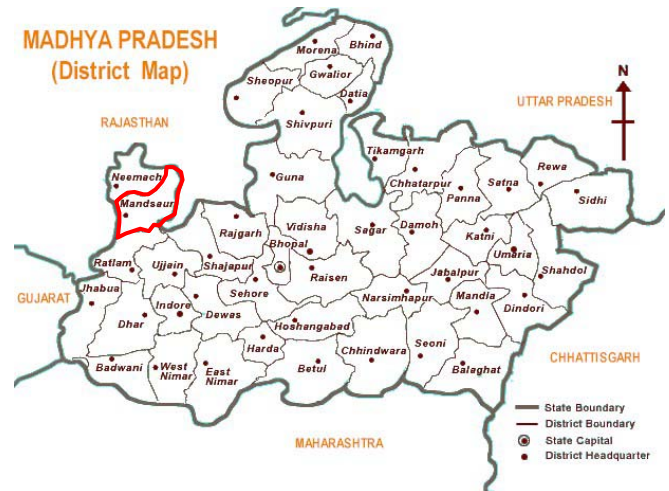


Fig. 2 District map of Madhya Pradesh [3]

3. CROP CHARACTERISTICS & FIELD SIZE

Opium poppy plant is a dicotyledon, unlike wheat or sugarcane, which are monocotyledons. Opium Poppy is cultivated during winter (rabi) season. Cold nights and warm days are needed for healthy plant growth and crop cycle is about 130-140 days. Flowering of opium poppy plant takes place between 85th - 95th day, flowers last for about 7 to 10 days. Pod initiation occurs around 100th – 110th day and lancing gets completed by 130th–140th day. Flowers of opium poppy come in various exotic color shades like, white, purple, pink etc. Among these opium poppy plants bearing white flowers is a high yield variety and is preferred by the cultivators. Average plant height is about 3 to 4 ft. Leaves of the plant are oblong or ovate shaped with an average leaf length of about 7 inches and average leaf width about 4 inches. There will be about 20-25 leaves per plant. There will be about 50 plants per square meter. Generally no spacing between plants is maintained in plain areas. Plants are watered every week but with no standing water. Among several crops observed on the ground in the study area opium poppy leaves have by far the maximum moisture content and spongy. Thus high inter cellular spacing and when fully grown

practically no exposure to back ground soil. The Leaf area of opium poppy is high compared with other crop types present in the area. Phenological cycle of opium poppy is shown in Fig.3.

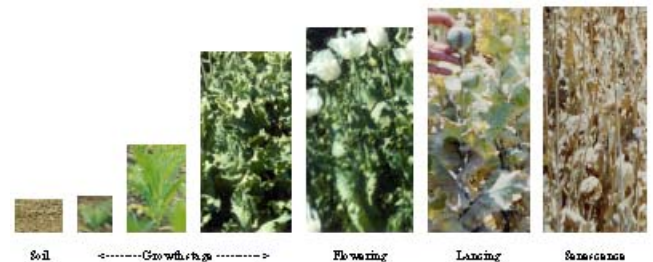


Figure 3: Phenological cycle of Opium Poppy

Each cultivator is given license for 2000 sq mts normally and in exceptional cases for 3000 sq mts. Although license is for 2000 sq mts due to shortage of water actual sown area can be less than 2000 sq mts.

4. DATA USED AND PRE-PROCESSING

- IRS-1D LISS-III data acquired during fallow and crop seasons for 2000,2001,2002,2003 seasons covering part of Mandsaur district, Madhya Pradesh and for 2003 season covering part of Chhattaugarh district, Rajasthan is used. However, results pertaining to 2002 season for Madhya Pradesh and 2003 season for Rajasthan are only presented.
- Survey of India topographic maps are used for image data rectification.
- Geographic coordinates collected using hand held GPS receiver for agricultural crop fields are used for training data selection and accuracy assessment.
- Necessary information like solar elevation angle, LMIN, LMAX read from the scene header and mean solar exoatmospheric spectral irradiance values are used together with the haze factor [5] and [6] calculated by taking 1% pixels occupying lower tail of histogram of respective bands to convert DN image to reflectance image using standard mathematical equation.
- As WDVI is a distance based index, relatively better atmospheric correction needs to be applied to the data, which is not necessary for ratio based indices like NDVI.

5. VEGETATION INDICES

The cells in plant leaves are very effective scatterer of light because of the high contrast in the index of refraction

between the water-rich cell content and the intercellular air spaces. Vegetation is very dark in visible range of

electromagnetic spectrum due to pigments (chlorophyll, xanthophyll, etc.), which occurs in leaves. It is especially so in the red region of the electromagnetic spectrum, whereas in the NIR region plants are very bright because of weak absorption in this spectral range, but the plant scatters strongly in this part of the electromagnetic spectrum. Vegetation Indices are algebraic combinations of remotely sensed spectral bands that can tell something useful about vegetation. The numerical value of a vegetation index brings out several important characteristics of a plant like its LAI and leaf type and structure, thereby indirectly helping in its identification and state of health.

Generally all vegetation indices assume that all bare soil in an image form a line in spectral space and are primarily concerned with Red-Near Infrared space, so a Red-Near Infrared line of bare soil is assumed. This line is considered to be the line of zero vegetation. The clustering behavior of vegetation and soil in Red-NIR space is shown in Fig 4.

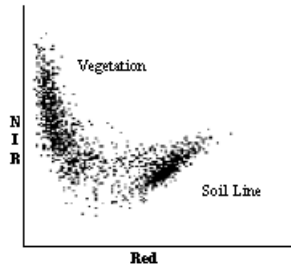


Figure 4: Soil and Vegetation Reflectance Scattergram

Vegetation indices like NDVI, RVI etc. measure the angle made with the soil line and are called as angular vegetation indices. Indices, which measure distance from the soil line like SAVI, WdVI, PVI etc. are called as distance based VI's. NDVI is the most extensively used vegetation index to characterize the amount of biomass, LAI etc.. But the difficulty with NDVI is that, if the crop density or LAI is high then NDVI value saturates and does not provide necessary discrimination among them. The main reason being that it does not minimize variable soil background effect and being ratio based tends to be non-linear exhibiting asymptotic behavior leading to insensitivity to vegetation variations over high LAI's and/or canopy covers. The limitation of NDVI in discriminating opium poppy from other crops is illustrated in Fig 5.

6. VEGETATION AND SOIL PIXEL EXTRACTION

It is well known that opium poppy being an agricultural crop; only agricultural fields and vegetation that has developed in these fields from beginning of the crop season to middle through end of crop season are of interest. Agricultural fields can be static or dynamic due to slash & burn of forest. The static fields will be in the plains for eg. Madhya Pradesh, Rajasthan and Uttar Pradesh. The dynamic fields are prevalent in areas where jhum cultivation is practiced, like

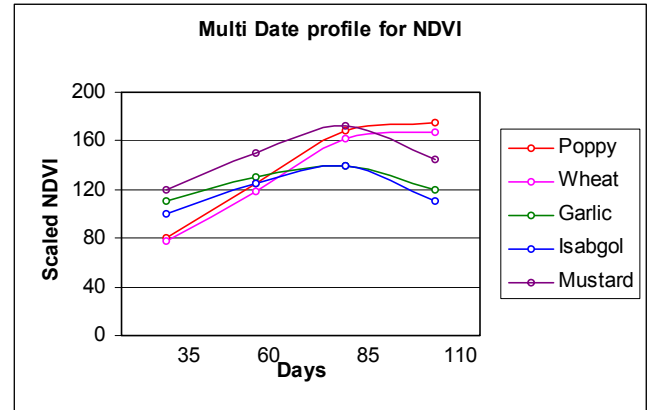


Fig. 5 Multi Date NDVI profile

IRS-1D LISS-III data acquired on 5th December 2001 (35th day), 30th December 2001 (60th day), 24th January 2002 (85th day) and 18th February 2002 (110th Day)

The limitation of NDVI can be circumvented if an index that can minimize the variable background effect is used. WdVI [4],[7] which is a distance-based index provides the necessary minimization of variable soil background effect thereby improving the discrimination between opium poppy and other crops.

WdVI is calculated as,

$$WdVI = NIR - g * Red \quad (1)$$

where, g = slope of soil line

Appropriate method to calculate soil line slope makes use of two atmospherically corrected images of the same area, where one image is taken during the growing season and other during fallow season. Using the crop and fallow season imagery WdVI takes the form

$$WdVI_{(crop)} = NIR_{(crop)} - g_{(fallow)} * Red_{(crop)} \quad (2)$$

WdVI value is directly proportional to the density of vegetative cover and number of leaf layers.

Inverse WdVI (IWDVI) is calculated as

$$IWDVI_{(crop)} = Red_{(crop)} - g_{(fallow)} * NIR_{(crop)} \quad (3)$$

where $g_{(fallow)}$ is calculated by swapping the X and Y-axis. The IWDVI value is directly proportional to the amount of soil component seen by the sensor.

Arunachal Pradesh in India, Thailand, Myanmar etc. Since, the image contains different kinds of land cover features like forest, shrubs, settlements, water bodies, agricultural crops etc. and as the interest is only in agricultural crops, other features can be eliminated from processing. Agricultural crops are extracted iteratively using radiometrically and geometrically corrected fallow and crop season image data as discussed below:

6.1 Iterative extraction of Vegetation and soil pixels from crop and fallow season images:

a) WdVI, IWDVI image composite creation for crop season image using soil line estimated from fallow season image.

The input images in this stage consist of all features types, viz. vegetation of all types, water bodies, built-up areas, wasteland, cloud etc. The soil line generated

in the first iteration is average representation of all the land cover types present in the fallow season image.

b) Filtering IWDVI by eliminating zero and positive values. All vegetation type features will be less than zero in IWDVI image. The other cover types like water

bodies, built-up areas, wasteland etc. have values greater than zero, which are eliminated by this filtering operation.

- c) Extracting pixels having negative value only from original fallow season and crop season image.

After this operation fallow season image consists of all types of vegetation and soil pixels.

- d) Generating WDV, IWDVI image composite using filtered fallow season image for soil line estimation.

The soil line generated in this stage is average representation of all types of vegetation and soil present in the fallow season image.

- e) Repeating Steps – (a) to (d) until slope of the soil line becomes stationary.

The repeat of the procedure eliminates shrub and waterweeds. Soil line stabilizes only if vegetation and soil pixels are present. The soil line at the end of iterations is fit between vegetation and soil land cover types.

- f) Ratio of NDVI_{crop} over NDVI_{fallow} is used to eliminate residual forest.

- g) Extracting soil pixels from fallow season and dynamic vegetation pixels from crop season images

- The filtered image of fallow season contains only soil pixels (bare agricultural fields).
- The filtered image of crop season contains only dynamic vegetation (agricultural crops).

The above sequences of operations ensures identification of agricultural plot soil pixels use of which can result in better estimation of soil line. The flow chart for automatic extraction of dynamic vegetation is show in Fig 6.

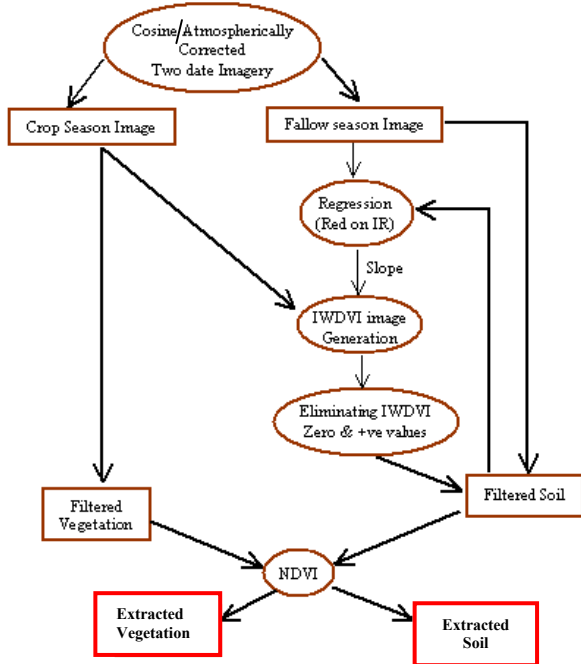


Figure 6. Flow Chart for Automatic Extraction of Dynamic Vegetation

Figure 7(a)–(d) shows section of IRS-1D LISS-III imagery covering part of Western Madhya Pradesh.

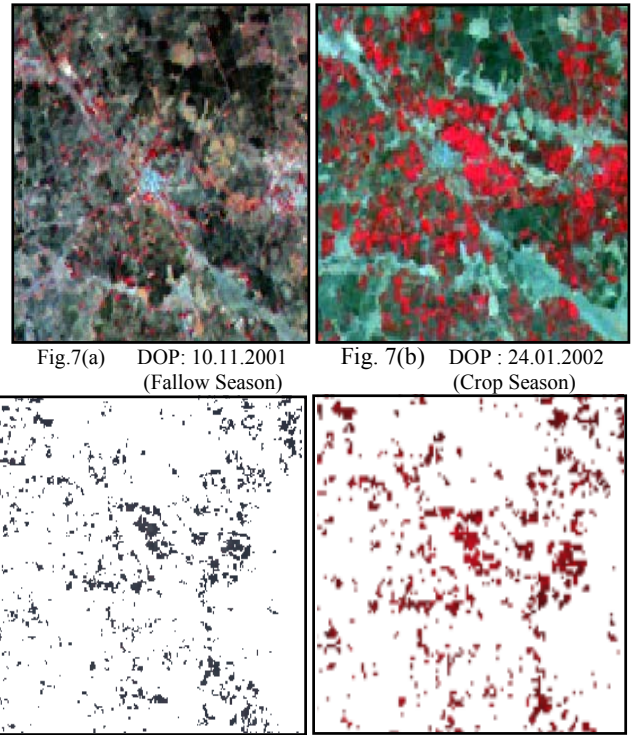


Fig. 7(a) DOP: 10.11.2001 (Fallow Season)

Fig. 7(b) DOP: 24.01.2002 (Crop Season)

Fig. 7(c) Extracted soil

Fig. 7(d) Extracted vegetation

From the multi-date WDV profile shown in figure (8) it can be observed that the image data acquired during 85th to 105th day will discriminate opium poppy from other crops.

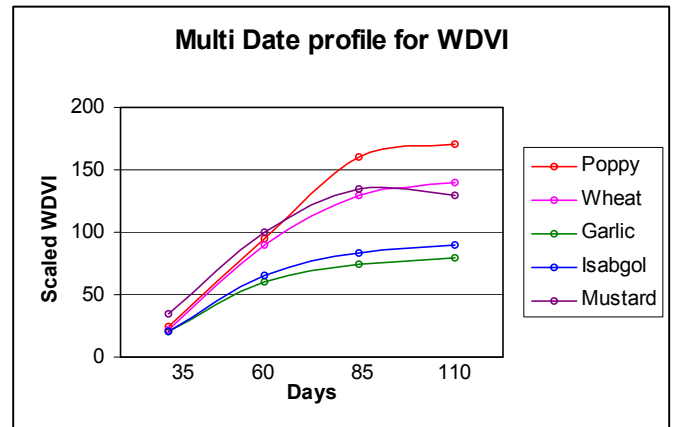


Figure 8 : WDV multi-date profile IRS-1D LISS-III data acquired on 5th December 2001 (35th day), 30th December 2001 (60th day), 24th January 2002 (85th day) and 18th February 2002 (110th Day)

However the level of discrimination is not similar across all growth stages, but maximum discrimination is possible when opium poppy is at its peak growth stage, i.e. flowering phase (85th to 110th day).

7. CLASSIFICATION

The two images WDV and IWDVI are displayed as color composite by assigning IWDVI image to red plane and WDV image to green and blue planes. Pixels of opium poppy appear in unique hue (cyan), as opium poppy crop has

high WDV and low IWDVI value. The color composite is used for training set identification and for performing maximum likelihood classification.

8. RESULTS

Ground truth information is collected using hand held GPS receiver during field visit to Mandsaur in Feb 2002 and is compared with the classified output to validate the results.

The GPS points overlaid on the image are shown in Fig.9 and Table-II shows accuracy totals.

Table-II Accuracy Totals

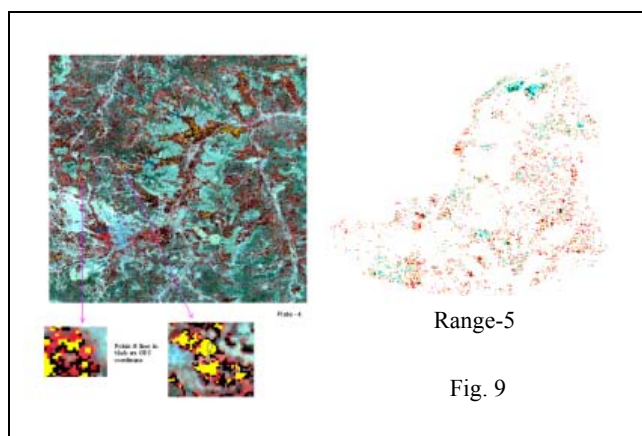
Class Name	Reference Totals	Classified Totals	Number correct	Producers Accuracy	Users Accuracy
Poppy	81	78	74	91.36%	94.87%
Wheat	76	62	51	67.11%	82.26%
Garlic	58	48	41	70.69%	85.42%
Isabgol	33	34	28	84.85%	86.15%
Mustard	50	51	36	72.00%	70.59%

Overall Classification Accuracy = 80.15%

Conditional Kappa each category

Class Name	Kappa
Poppy	0.93
Wheat	0.79
Garlic	0.83
Isabgol	0.81
Mustard	0.67

Overall Kappa Statistics =0.77



CYAN & YELLOW – Opium Poppy
 Acreage as per Government Of India Officials: 226.5 hectares
 Acreage estimated from image: 242 hectare
 Overestimation from image - About 7%

Fig 10(a). shows IRS-1DLISS-III acquired on March 03, 2003 & Fig 10(b). WdVI stack covering Ravalia Village,

Chittaurgarh District, Rajasthan and Table-III shows village level acreage estimation

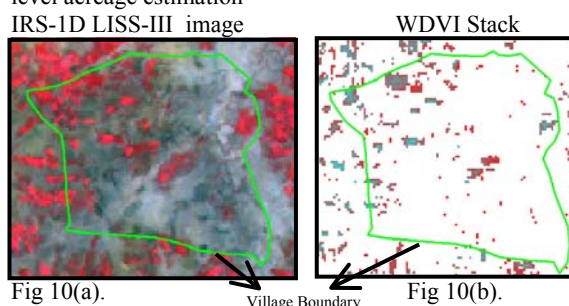


Table-III

Opium poppy acreage (in hectares)	
As per Government of India Officials	2.222
Estimate from image (Acquired on 03 rd March 2003)	2.327
% Difference	+ 4.5%

9. CONCLUSION

The Weighted Difference Vegetation Index is observed to be useful in discriminating between winter wheat and opium poppy. WdVI and IWDVI image composite enables selection of training sets for classification. Although IRS-1D LISS-III has 23.5 meter spatial using the method discussed it will be possible to obtain range (eight to ten villages comprise one range) level opium poppy crop acreage estimates with reasonable accuracy. If the fields are relatively large and contiguous village level acreage estimates with reasonable accuracy can also be obtained, like

in the case of Ravalia ,Chittaurgarh. Although results were presented for 2002 (part of western Madhya Pradesh) and 2003 (Ravalia village, Chittaurgarh district, Rajasthan) season only, results from the application of the methodology for 2000, 2001 and 2003 seasons using IRS-1C/1D LISS-III data are observed to be consistent with ground situation. Cultivator level information can be extracted from recently launched IRS-P6 LISS-IV data. In the next phase of the work attempt will be made to extract cultivator level information using IRS-P6 LISS-IV data.

10. REFERENCES

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