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Acreage estimation of Isabgol (*Plantago ovata* Forsk) using remote sensing and geographic information system

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ABSTRACT

A feasibility study for assessing acreage of Isabgol using remote sensing data was carried out. Traditionally, crop acreage estimated based on land records is cumbersome, costly and time consuming. No remote sensing-based methods available for acreage estimation of Isabgol. Unsupervised classification with ISODATA clustering technique was applied to multi date LISS-III data to generate different classes which were segregated using Soil Adjusted Vegetation Index (SAVI) spectral profile of crops grown along with Isabgol. Six date SAVI data was used to generate spectral signature of candidate crop and other crops. SAVI ranged from 0.09 to 0.19 for Isabgol. The estimated Isabgol acreage was around 1675 ha, 5753 ha and 4120 ha for Bhachau, Rapar and Santalpur blocks, respectively with a classification accuracy of 80% and Kappa coefficient of 0.72. Accurate estimation of area will help planning and export management of Isabgol in the country.

Keywords: *Crop acreage, Isabgol, ISODATA clustering, Medicinal crop, Multi date LISS-III, Soil Adjusted Vegetation Index (SAVI)*

INTRODUCTION

Remote sensing techniques have demonstrated potentiality in providing information of the characteristics and spatial distribution of natural resources including agricultural resources because of their unique advantages of providing multi-spectral, multi-temporal and multi-spatial resolutions. Use of satellite remote sensing data has also proved to be more cost effective, reliable, timely and faster than the conventional ground-based surveys of agricultural resources. Spectral reflectance data obtained from remote sensing is a manifestation of integrated effect of weather, soil, cultural practices and crop characteristics that can be used in identifying and monitoring crop growth and for estimating crop yield (Yedage *et al*., 2013).

Medicinal plants form the important raw drugs for various traditional systems of medicines (Manivel *et al*., 2019). Medicinal plants are obtained either from wild (80%) or cultivated (20%). Medicinal plants cultivation ensures purity, authenticity and availability of raw drugs to industries. The demand for medicinal plants across the globe is increasing. Acreage estimation of medicinal plants facilitates micro level planning and demand analysis. Even though space technology was used in many agriculture crops, there are very few studies were carried out for medicinal plants. The integrated use of geographic information systems (GIS) and ground surveys to map medicinal and herbal (MH) plants in a semi-arid and arid Mediterranean area in the north-west of Jordan was carried out by Al-Bakri *et al*. (2011). Salem (2003) applied GIS-based approach to the spatial analysis of endangered arboreal species in Egypt. GIS method for assessing chemodiversity in medicinal plants (Moraes et al., 2005) was reported. Wu *et al*. (2019) developed global medicinal plant geographic information system (GMPGIS) to analyze environmental information of ecologically suitable regions in China.

Isabgol (*Plantago ovata* Forsk) is a high value medicinal plant cultivated in India. Isabgol husk is the economic part, has medicinal value, used as natural fiber as well as laxative. Isabgol husk traded as Psyllium husk has many industrial applications too (Patel *et al.*, 2020). India is the largest exporter of Isabgol in the world, mainly produced in arid zone of Gujarat, Madhya Pradesh, Haryana, Uttar Pradesh and Rajasthan (Janakiram *et al*., 2019).

Although Isabgol largely cultivated in India, non-availability of precise information on area and production is a major impediment to the development of Isabgol based industry. At present, Isabgol acreage is obtained from conventional data collection techniques such as field visits on ground and from reports. These reports are often subjective, involve more time and money. Often prone to large errors due to inadequate ground observations, leads to poor crop yield production estimates. The accurate estimation of Isabgol acreage is essential for various planning purposes, including pricing, export/import and contingency measures. Numerous researches have been carried out for acreage estimation by different researcher for different crops. Singh *et al*. (2005) applied maximum likelihood classification approach with IRS LISS-III data for village level crop area estimation. The soyabean acreage estimation and crop production was estimated with help of MODIS (TERRA) satellite data and GIS database for some district of Madhya Pradesh (Maurya, 2011). Husak *et al*. (2008) used hybrid high-medium resolution technique for estimation of cropped area for central Ethiopia. Yedage *et al*. (2013) used IRS P6 LISS-III data for finding out minimum and maximum concentration of sugarcane using Bhatia concentration index (yr) for all tehsils of Solapur district in Maharashtra state. An unsupervised classification was applied to multidate IRS LISS-III data to estimate the rice acreage (Naidu and Giridhar, 2016). Rajak *et al*. (2016) estimated early crop area using multidate MODIS data and two date AWiFS data for Gujarat. The study aims at determining the optimum method for precise estimates of acreage of Isabgol using remote sensing and geographic information system. Isabgol acreage was estimated in three block of Gujarat during *Rabi* 2018-19. Accurate estimates of isabgol acreage will help plan production, pricing and export of Isabgol in the country.

METHODOLOGY

Study area and season

The study was conducted on three blocks namely Bhachau, Rapar and Santalpur block of Gujarat state (Fig.1) during Rabi season of 2018-19. An ideal sowing time of Isabgol was in fortnight of November and harvest during March-April.

Satellite data used

A multi-date LISS-III data (Table 1) of *Rabi* season of 2018-19 was used in this study. Six cloud free data of isabgol growing season available from start of December to mid of February was used for analysis.

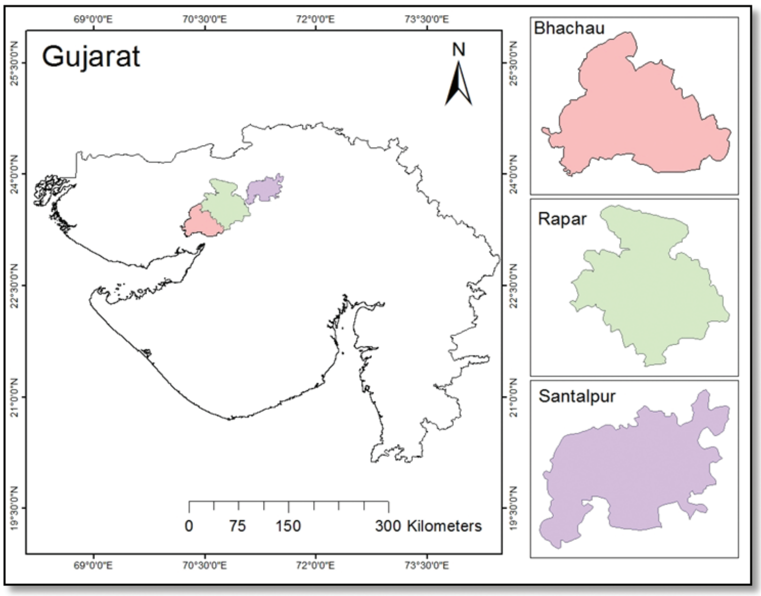

Fig. 1: Geographical location of the study area

Table 1: Characteristics of LISS-III imageries

Characteristic	Value	Path	Date of Pass
Spectral band: Green (B2)	0.52 – 0.59 μm	91/55	05-12-2018
Spectral band: Red (B3)	0.62 – 0.68 μm		29-12-2018
Spectral band: NIR (B4)	0.77 – 0.86 μm		10-01-2019
Spectral band: MIR (B5)	1.55 – 1.70 μm		22-01-2019
Spatial Resolution	23 m		03-02-2019
Swath	142 km		15-02-2019
Revisit time	24 days		
Quantisation	10 Bit		

Field data

Primary level survey was carried out in the study area for collection of ground truth at 193 locations using hand held GPS for the available crops and farmers were interviewed for the farming systems and management techniques for the Isabgol crops.

Preprocessing of satellite data

Co-registration

Spatial characteristics of any object including crop derive from different time need to have common geo-referencing so that they can be integrated. An auto image co-registration technique called Auto Image Registration Software (AIRS) developed by Space Applications Center (SAC), Ahmedabad was used for co-registering the satellite images in batch mode keeping all dates of a particular path and row at a time and a reference image.

DN to Radiance conversion

Satellite provides raw data in Digital Number (DN) which was converted into radiance and then into the TOA reflectance using the equation.

$$L = \frac{DN * L_{max}}{DN_{max}} \quad \dots (1)$$

Where, L is radiance, DN is Digital Number for a particular pixel, Lmax maximum radiance for the given band and DNmax depends on sensor. LISS-III provides 10-bit data therefore 1023 is taken as DNmax.

Radiance to TOA Reflectance

$$\rho_{TOA} = \frac{\pi * rad * (U)^2}{E_0 * \cos\theta} \quad \dots (2)$$

Where U = 1/R, Here U is the Sun Earth distance

And $R = 1.00011 + 0.034221\cos(\gamma) + 0.00128\sin(\gamma) + 0.000719 *\cos(2\gamma) + 0.000077\sin(2\gamma)$

Where,

$$Gamma(\gamma) = \frac{(2*\pi)*(J.D-1)}{365} \quad \dots (3)$$

Where, J.D is Julian Day or Day of year.

E0 is Extra-terrestrial irradiance in mW/cm-2/μm [Pandya *et al*., 2002]

Soil Adjusted Vegetation Index (SAVI)

A distance-based vegetation index soil adjusted vegetation index (SAVI) was used. Distance-based vegetation indices cancel or diminish the effect of soil brightness in cases where vegetation is sparse. i.e., the pixels in the image are a combination of vegetation and soil information. SAVI tends to minimize soil brightness, a phenomenon that has been demonstrated (Miura *et al*., 2000, Cao *et al*., 2014; Pop *et al*., 2019). Huete (1988) introduced a soil calibration factor in the NDVI equation to account for the first order soil-vegetation optical interactions. The calibration factor of 0.5 was used. SAVI is defined as

$$SAVI = \frac{(NIR - RED)}{(NIR + RED + L)} X (1 + L)$$

Where,

NIR is the reflectance in the near infrared

RED is the reflectance for red

L is a constant that is a surrogate for LAI, Huete (1988)

Crop classification

A ISODATA (Iterative Self-Organizing data analysis technique) clustering algorithm was used to perform an unsupervised classification of the image pixels into spectral clusters. Each cluster represents a group of pixels which have similar spectral characteristics in the input bands. The ISODATA clustering method starts by arbitrarily establishing N cluster means based on the means and standard deviations of the bands in the input file ("N" is a number specified by the user, this was essentially the number of classes you are trying to classify). A minimum distance criterion was then used to assign each pixel to the "nearest" cluster. The cluster means were recalculated and each individual pixel was again compared to the new cluster means and assigned to the nearest cluster, this process was iterated a specified number of times up to proper discrimination of required crop was achieved. Here, we have applied ISODATA clustering technique on multi date SAVI stack layer image. Initially 70 minimum and 75 maximum classes, 30 iterations and convergence threshold 0.999 was given during first classification for separation of agriculture and non agriculture land. The classes were grouped, based on spectral similarity and closeness to the similar signature. GPS based ground truth data was used to validate temporal profile of Isabgol. Each group of class was match with ideal spectral signature of ground truth data and assigned class name. Here, we have observed classes with similar SAVI series were merged in the single class. It showed significant mixing with similar spectral signature crops i.e. cumin. So, it was reclassified using ISODATA algorithm. Following the classifications, a 3 × 3 averaging filter was applied to the results to remove unwanted single pixels for clean up the speckling effect in the imagery (Fig. 2).

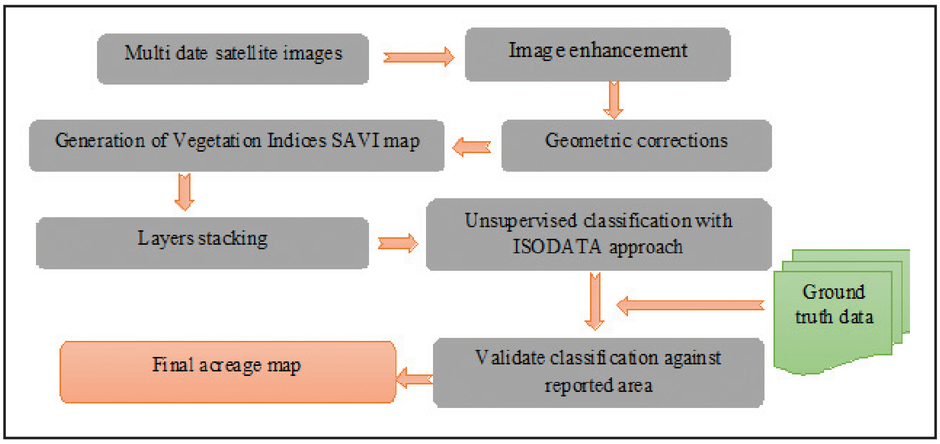

Fig. 2 : Flow diagram showing the methods need for acreage estimation

RESULTS AND DISCUSSION

Spectral Profile of Isabgol and competing crop in the season

Crop identification and acreage estimation using remote sensing imageries was carried out based on unique spectral signature of each crop. The profile patterns were studied to understand their growth pattern for identification and discrimination of Isabgol from competing crops. Six date SAVI data was used to generate spectral signature of crops (Fig. 3). SAVI from isabgol ranged from 0.09 to 0.19, which was relatively low but higher than cumin (0.03 to 0.17). It was observed that SAVI of isabgol and cumin goes parallel throughout the season which may be due to nearly similar phenology of candidate crops (Isabgol and cumin) such as plant height, canopy and growth. Earlier, similar observation was found for maize and soyabean (Ghazaryan *et al*., 2018). Highest SAVI was achieved at the pre flowering stage of isabgol at the mid of February under Gujarat conditions. The SAVI for castor and mustard are comparatively higher than Isabgol and Cumin. Castor and mustard are much taller than isabgol, also have a totally different phenological cycle were easily separable.

Acreage

The identified Isabgol and mixing crop area were recoded and second stage classification was carried out with 30 clusters to estimate the acreage. Then the last recode was applied to generate Isabgol area alone. The final acreage map (Fig.4) along with their false colour composition (FCC) image were generated for each block. Acreage was estimated through complete enumeration technique of classified pixels. The final estimated area of Bhachau, Rapar and Santalpur block was around 1675 ha, 5762 ha and 4120 ha respectively. The estimated area needs to be compared with the area available on land records for method validation, such information was not available for the selected blocks at time of study.

Accuracy assessment

The accuracy is concerned with the correspondence between class label and 'true' class. A 'true' class is defined as what is observed on the ground during field surveys. Accuracy assessment determines the quality of information derived from remotely sensed data. The confusion matrix (Foody, 2002) was generated for the blocks (Table 2) for assessing the classification accuracy. The overall classification accuracy achieved was about 80% with Kappa coefficient of 0.72. Higher producer's accuracy of about 92% and user's accuracy of 82% was achieved for Isabgol. It showed some confusion with cumin crop for which users and producer's accuracy were 85% and 70% respectively. Earlier, similar observation was reported as maize class confused with soyabean and double crop (Azar *et al.*, 2018).

CONCLUSION

A pilot study to estimate the acreage of Isabgol was undertaken in three blocks (Bhachau, Rapar and Santalpur) of Gujarat, India for the first time. A simple and high accurate method developed for acreage estimation of Isabgol will help in early forecast of supply and demand. Two stage ISODATA clustering classification technique was used to discriminate different classes. The estimated area was 1675 ha, 5762 ha and 4120 ha respectively

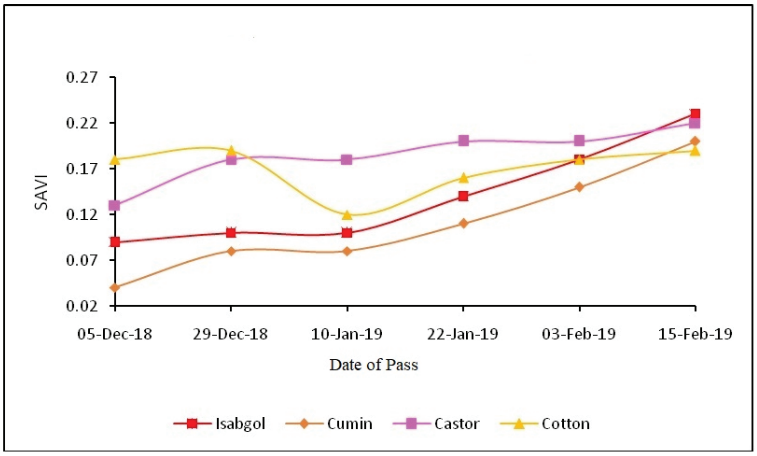

Fig. 3: Spectral profile of different crops

Table 2: Confusion matrix and kappa coefficient for Bhachau, Rapar, Santalpur blocks

Crops	Isabgol	Cumin	Mustard	Castor	User's accuracy (%)	Producer's accuracy (%)
Isabgol	24	5	0	0	82	92
Cumin	2	12	0	0	85	70
Mustard	0	0	22	8	73	84
Castor	0	0	4	18	81.8	69

Overall Accuracy = 80%, Kappa coefficient =0.72

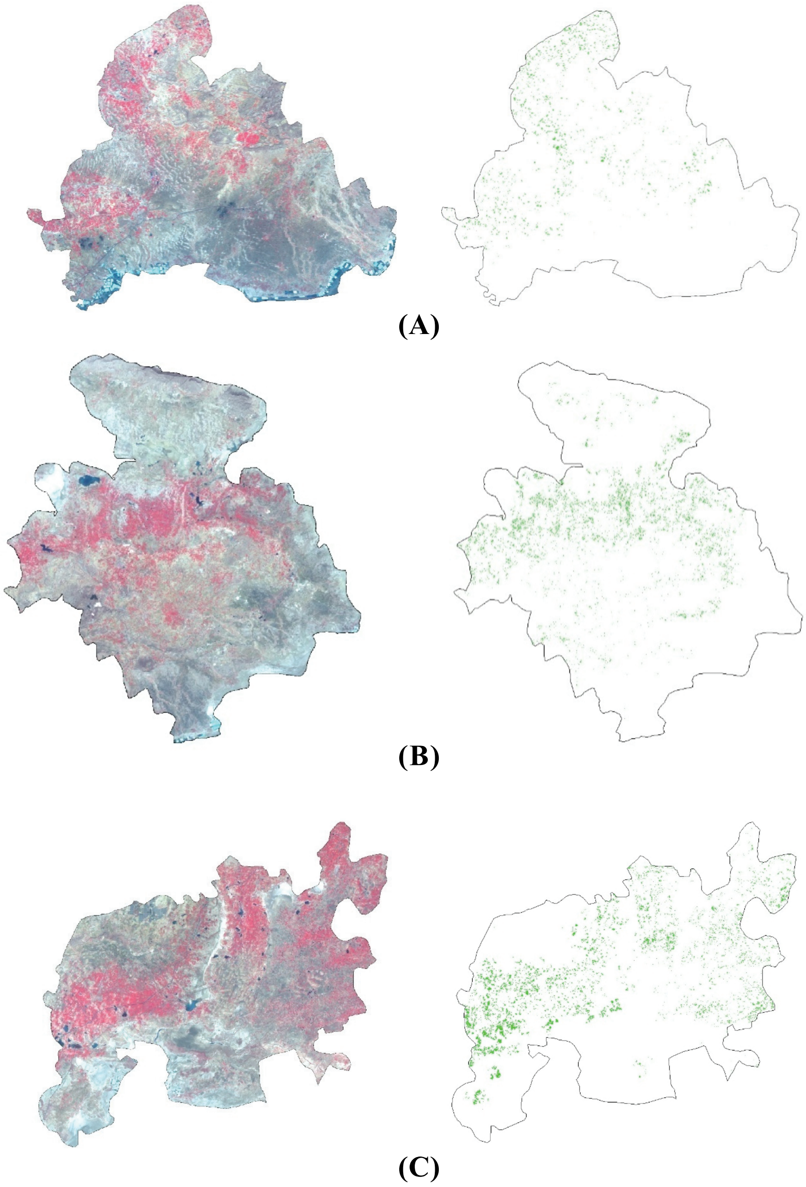

Fig. 4: False color composite (FCC) and classified map of block under study (A) Bhachau (B) Rapar and (C) Santalpur

for Bhachau, Rapar and Santalpur block. Integrated use of remote sensing, GIS and Ground truth data for accurate, timely and cost-effective acreage estimation of crop plants will help in early estimation of acreage. Accurate estimation of isabgol area and expansion of existing area will help planning and export management of isabgol in the country.

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