RESEARCH ARTICLE

Generating Banana area map using VV and VH Polarized Radar Satellite Image

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ABSTRACT

An investigation was carried out to generate banana area map in major banana growing districts of Tamil Nadu using polarized (VV and VH) Synthetic Aperture Radar Satellite images Sentinel 1A SAR Data with VV and VH polarization at 12days interval were downloaded for the crop growing season. Crop parameter for classification was retrieved by continuous monitoring across the study area Ground truth collection and accuracy assessment was carried out using the validation points. Using temporal data collected for the cropping period, spectral dB curve was generated for VV and VH polarization. The dB values do not show much variation both under VV and VH polarization. The total banana cultivated area as estimated for Tiruchirappali, Karur and Erode districts were 5457 hectares, 3865 hectares, and 9432 hectares respectively.

Keywords: *VV and VH Polarization, Sentinel-1A, SAR, Banana, Accuracy*

INTRODUCTION

India is one of the largest producer of Banana fruits in the world and occupies an important position in the Indian agricultural economy. Banana is an excellent source of potassium, protein and carbohydrates and contains negligible amount of fat.In India banana is largely grown in the states of Tamil Nadu, Maharashtra, Karnataka, Gujarat, Andhra Pradesh, Assam and Madhya Pradesh. In the state of Tamil Nadu, Banana is majorly grown in the districts of Theni, Tiruchirappalli, Coimbatore, Tuticorin and Karur.

A crop information system is one way that remote sensing can provide valuable information to decision-makers. Remote sensing is presently the only technology that can provide timely and accurate crop inventory information. Conventional method of data collection, compilation and publication are reliable but fails to serve the information in real time. For overcoming this situation, the use of remote sensing technology can be incorporated that provides timely and accurate information along with high revisit frequency and spatial resolution. Thus, there is a need to gather and generate information on the area and their spatial extent in which contribution of geospatial technologies viz., remote sensing, GIS and GPS are immense.

In the past, crop identification and area estimation was fairly successful using space borne sensors operated in the visible and near infrared regions of theSpectrum (Fisetteet *al*., 2005).In early use, optical remote sensing measures the reflectance from objects in the visible and infrared portions of the electromagnetic spectrum. The amount of reflectance is a function of bio-physical characteristics of the reflecting feature (e.g., canopy moisture, leaf area and level of greenness of vegetation). Since different crops at varying vegetative stages exhibits different bio-physical characteristics and optical images have been useful in crop mapping studies. However, optical sensors has its own limitation in image acquisition during cloudy or rainy conditions.

The microwave remote sensing capability to penetrate clouds and to some extent rain and ability to collect data any time during a day and any season during the year. It is also sensitive to soil and vegetation moisture and surface roughness. These capabilities made the microwave sensor to collect the data during rainy season and monitor the crops. SAR imagery helps in regular crop mapping and monitoring. SAR back-scattering is a primary function used for land cover mapping, target detection and monitoring of changes found in ground features within areas of interest. The changes in the mechanism of backscattering components of SAR images are utilized for crop identification (Pinter *et al*., 2003). Patel *et al*. (1995) utilized ERS-1A SAR multi temporal data for rice crop identification. The results shows that a combination of SAR data acquired at the various rice crop stages helped in identifying and estimating areas of low land rice. Lam-Dao*et al*. (2007) attempted monitoring and

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mapping rice cropping system in Giang Province, Mekong river delta using ENVISAT ASAR data with dual polarization *viz.,* HH polarization and VV polarization. With these background knowledge,the present study was carried out to map banana crop in Tiruchirappali, Karur, and Erode districts of Tamil Nadu using Sentinel-1A SAR data.

MATERIALS AND METHODS

Study area

The study area comprises of major banana growing districts of Tamil Nadu *viz.*, Tiruchirappalli,Karur and Erode.

The Sentinel-1A mission is a European Radar Observatory for the Copernicus joint initiative of the European Commission (EC) and the European Space Agency (ESA). The Sentinel-1A mission includes C-band imaging operating in four exclusive imaging modes with different resolution (down to 5 m) and coverage (up to 400 km swath). It provides dual polarization capability (VV and VH), very short revisit times and rapid product delivery. For each observation, precise measurements of spacecraft position and altitude are available. Sentinel-1A has four standard operational modes, designed for interoperability with other system. In the present study, level 1 ground range (GRD) product obtained by interferometric wide (IW) swath mode of 20m resolution with 12 days of temporal resolution was used.

Pre-Processing of SAR data

A fully automated processing chain developed by Holeczet *al.* (2013) was used to convert SAR GRD multi-temporal data to terrain geo-coded σ° values. The processing chain itself is a module within the MAPscape-RICE software. The basic processing includes the following steps.

Strip mosaicking - to facilitate the overall data processing and data handling.

Co-registration - Images acquired with the same observation geometry were co registered in slant range geometry.

Time-series speckle filtering -to balance differences in reflectivity between images

Terrain geocoding -Radiometric calibration and normalization.

Anisotropic non-linear diffusion (ANLD) filtering – to getsmoothened homogeneous targets.

Removal of atmospheric attenuation - σ° values were corrected by means of an interpolator.

Parameterized classification

The parameterized classification algorithm quantitatively evaluated the variance and covariance of the category by spectral response pattern while classifying an unknown pixel. In this study, image classification was carried out using MTF algorithm with extracted multi-temporal features from Ground Range Detected (GRD) and Single Looking Complex (SLC) SAR images for the identification of Banana. Values extracted from multi-temporal features for Banana crop was used to create training polygons. The multi-temporal features used are VH_{max},VV_{Max},VV_{min}, VH_{maxD}, $VV_{minD}$and VH_{Min}, VV_{Mean}, Max Date and Min Date corresponding to the highest detected backscatter in the input series.

Max Date - Date corresponding to the highest detected backscatter in the input series.

Min Date - Date corresponding to the lowest detected backscatter.

The training polygons were used to generate mask to include Banana class while performing Banana area classification using Sigma Naught (σ°) of VV and VH all dates.

Accuracy assessment

The error matrix and Kappa statistics are used for evaluating the classification accuracy. The class allocation of each pixel in classified image is compared with the corresponding class allocation on reference data to determine the classification accuracy (Congalton, 1991). Forty per cent of the total ground reference data are used for validation and the pixels of agreement and disagreement are compiled in the form of an error matrix.Ground truths were performed in the study area to identify the banana. Totally 94 banana points and 52 non-banana points were collected during the ground survey for training and validation purposes.

Kappa Coefficient

Kappa coefficient is another measure of classification accuracy. It is a measure of the proportional improvement by the classifier over a purely random assignment to classes.

RESULTS AND DISCUSSION

Radar backscattering signature

Radar back scattering expressed as back scattering coefficient (dB or $σ^0$) derived from the vegetation surface is a measure of crop biomass, leaf area, plant height and soil properties, especially moisture content. Sentinel-1A SAR data acquired during the cropping period were analysed to derive backscattering signature so as to identify banana and non-banana features. Training pixels collected during ground truth verification was used to extract the unique temporal backscattering signature for banana. This was performed by stacking the multi temporal SAR data acquired over the study area.

Table1.Cumulative temporal backscattering values (dB) of banana for Tiruchirappalli and Karur districts

VV Polarization				VH Polarization			
Satellite Pass	Minimum	Maximum	Mean	Satellite Pass	Minimum	Maximum	Mean
D1	-8.532	-4.162	-6.229	D1	-14.412	-9.968	-12.209
D2	-8.942	-5.838	-7.426	D2	-15.026	-11.697	-13.445
D3	-9.031	-5.782	-7.268	D3	-15.603	-11.613	-13.359
D4	-8.865	-5.021	-6.847	D4	-15.247	-10.973	-13.019
D5	-8.193	-4.737	-6.584	D5	-14.705	-11.020	-12.840
D6	-8.043	-4.913	-6.680	D6	-14.871	-11.381	-12.997
D7	-8.112	-5.073	-6.733	D7	-15.377	-11.437	-13.041
D8	-8.235	-5.166	-6.713	D8	-15.409	-11.56	-13.119
D9	-8.481	-5.119	-6.753	D9	-15.441	-11.654	-13.290
D10	-8.108	-4.92	-6.502	D10	-14.719	-11.620	-13.081
D11	-8.067	-4.783	-6.329	D11	-14.489	-11.623	-12.904
D12	-8.192	-4.636	-6.393	D12	-14.791	-11.571	-12.965
D13	-8.271	-4.373	-6.243	D13	-14.927	-11.439	-12.877
D14	-8.210	-4.626	-6.303	D14	-14.670	-11.412	-12.848
D15	-8.150	-4.235	-6.400	D15	-15.050	-11.426	-12.907
D16	-7.421	-5.578	-6.442	D16	-14.098	-11.592	-13.279
D17	-8.480	-4.510	-6.563	D17	-14.029	-11.681	-13.238
D18	-8.069	-4.262	-6.488	D18	-14.128	-12.214	-13.229
D19	-8.077	-5.551	-6.668	D19	-14.011	-12.530	-13.316
D20	-7.245	-4.462	-6.159	D20	-14.047	-12.420	-13.38
D21	-8.425	-5.039	-6.517	D21	-14.269	-12.229	-13.424
D22	-7.6738	-5.116	-6.082	D22	-14.189	-12.116	-13.447
D23	-8.0231	-5.030	-6.524	D23	-14.551	-12.187	-13.459
D24	-8.2607	-4.753	-6.462	D24	-14.718	-12.465	-13.406
D25	-7.9164	-5.195	-6.532	D25	-13.803	-12.315	-13.047

Tiruchirappalli and Karur districts

In Tiruchirappalli and Karur districts the spectral curve showed variation in minimum, maximum and mean values for VV and VH polarization. The cumulative temporal backscattering values dB of banana crop from VV polarization is presented in Table 1. Where in satellite pass date wise minimum, maximum, mean radar backscattering values (dB) are presented. The minimum dB value during the cropping period (from D1 to D25) ranged from -9.032 to -7.245 and the maximum ranged from -5.838 to -4.162 and the mean value ranged from -7.426 dB to -6.082 dB. The date wise dB value indicates low during initial date of SAR data collection and slight increase was observed as the banana growth stage advances

Table 2.Cumulative temporal backscattering values (dB) of banana for Erode district

VV Polarization				VH Polarization			
Satellite Pass	Minimum	Maximum	Mean	Satellite Pass	Minimum	Maximum	Mean
	-10.189	-7.509	-8.764		-17.564	-14.349	-15.959
D2	-10.092	-7.328	-8.735	D2	-17.57	-14.665	-16.053
D3	-10.391	-6.686	-8.653	D3	-17.365	-14.86	-16.059
D4	-10.689	-6.045	-8.572	D4	-17.106	-14.747	-16.149
D5	-10.366	-6.358	-8.321	D5	-18.057	-14.749	-16.222
D6	-10.043	-6.672	-8.070	D6	-16.788	-14.476	-15.642
D7	-9.928	-7.402	-9.016	D7	-16.682	-14.331	-15.423
D8	-10.203	-8.097	-9.332	D8	-17.961	-14.529	-15.833
D9	-10.39	-7.993	-9.368	D9	-17.857	-14.756	-15.996
D10	-10.437	-7.991	-9.374	D10	-17.756	-14.88	-16.023
D11	-10.485	-7.716	-9.100	D11	-17.647	-14.236	-15.772
D12	-9.324	-5.561	-7.622	D12	-15.25	-13.249	-14.387

The cumulative temporal backscattering values (dB) of banana for VH polarization is presented in Table 1. The minimum dB value during date (D1 to D25) ranged from -15.603 to -13.803 and the maximum value ranged from -12.5302 to -9.968 with a mean value range of -13.459 to -12.209. The temporal backscattering value during the cropping period does not show much variation *i.e.* from early growth stage to maturity of banana.

Table 3. Banana area estimation for Tiruchirappalli, Karur and Erode district

District	Block	Estimated Area in Hectare
Tiruchirappalli	Tattayyangarpettai	30
	Thottiam	500
	Manachanallur	581
	Musiri	686
	Lalgudi	969
	Andanallur	1257
	Thiruverambur	1524
	Total Area	5457
Karur	Karur	327
	Thogamalai	467
	Krishnarayapuram	555
	Kulithalai	2516
	Total Area	3865
Erode	Nambiyur	90
	Thalavadi	216
	Gobichettipalayam	254
	Bhavani	362
	Bhavanisagar	512
	T.N. Palayam	1353
	Sathyamangalam	2098
	Anthiyur	3987
	Total Area	9432

Erode districts

The cumulative temporal backscattering values dB of banana crop from VV polarization is presented in Table 2. Satellite pass date wise data on minimum, maximum and mean radar backscattering values (dB) are presented.

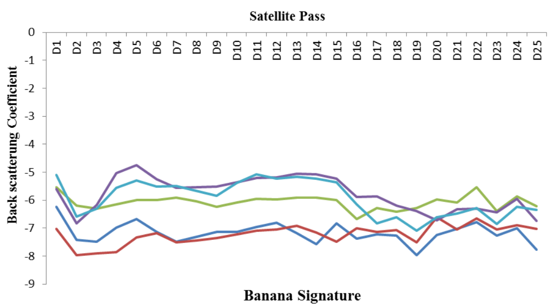

Figure 1.Temporal Back scattering signature of banana crop in VV polarization at different GT points

The minimum dB value during the cropping period (from D1 to D12) ranged from -10.689 to -9.324 dB and the maximum ranged from -6.621 to -5.561 dB whereas mean value ranged from -9.374 to -8.070 dB. Among the dates the dB values were high during initial date of SAR data collection and slight decrease was observed as the banana growth stage advances.

The cumulative temporal backscattering values (dB) of banana for VH polarization is presented in Table 2. The minimum dB value during date (D1 to D12) ranged from -18.057 to -17.106 and the maximum value ranged from -14.756 to -13.249 with mean value range of -16.222 to -15.423. The temporal backscattering value during the cropping period does not show much variation i.e. early growth stage to maturity of banana.

Radar backscattering value (dB) extracted from multi temporal satellite images for various ground truth points were low for VV polarization, wherein the value ranged from -9.0 to -4.0 dB.

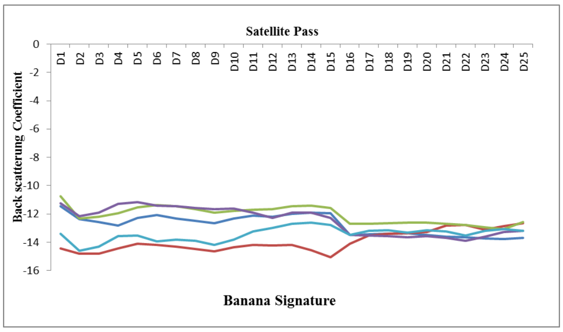

Figure 2.Temporal Back scattering signature of banana crop in VH polarization at different GT points

Whereas the dB values for VH polarization ranged from -15 to -10. Aubertet *al*. (2011) reported that VV polarization mode of data acquisition is more sensitive to surface variation than the VH polarization mode.

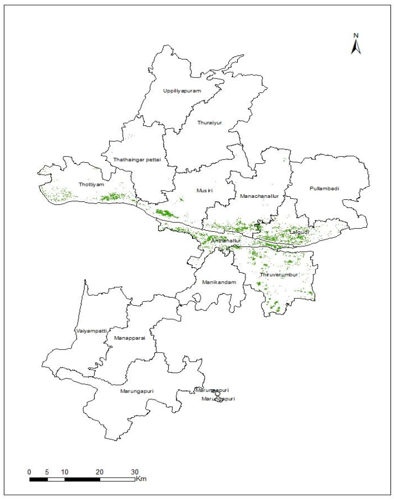

Figure 3. Banana Growing Area in Tiruchirappalli District of Tamil Nadu

The backscattering values were low at the end of the cropping period or at maturity as reported by Lillesand and Kiefer (1994) wherein the decrease in backscatter may be caused by maturity of the crop, or vegetation biomass as reported by Skriveret *al*. (1999) and or related to the reduced volumetric scattering due to maturity as reported by Panigrahy and Mishra (2003).

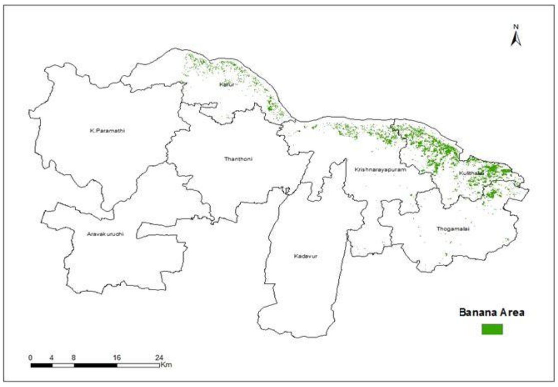

Figure 4. Banana Growing Area in Karur District of Tamil Nadu

The temporal behavior of backscattering of banana for Tiruchirappalli and Karur districts derived from VV and VH polarization are shown in Fig 1and 2 respectively. The temporal backscattering signature do not show much variation both under VV and VH polarization, this is presumably due to the persistence of greenness throughout the cropping period and broad leaf features as reported by Wang Xiaoqin*et al*. (2009).

The banana area derived from multi-temporal SAR imagery of Sentinel-1A through parameterized classification algorithm for Tiruchirappalli, Karur and Erode districtsare show in (Fig.3 and 4. The total banana cultivated area as estimated for Tiruchirappalli and Karur districts were 5457 hectares and 3865 hectares, respectively. In Erode district the estimated area (Figure 5) under banana was 9432 hectares.

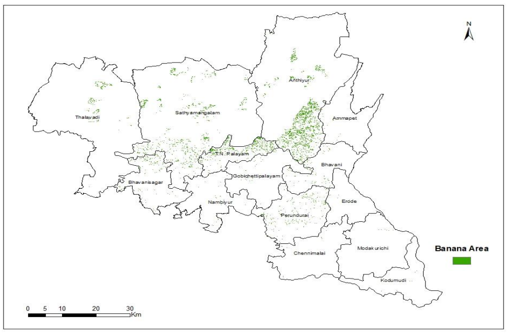

Figure 5. Banana Growing Area in Erode District of Tamil Nadu

The classification accuracy of the banana area estimated from Sentinel-1A multi-temporal SAR data for Tiruchirappalli and Karur district was 86.3 percent (average accuracy) and 87.9 (overall accuracy) The kappa index was 0.73.The average and overall average classification accuracy for Erode district were 88.6 percent and 86.0 percent, respectively. The kappa index obtained was 0.76.

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