

Original Research Article

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Rice Acreage Estimation Using Sentinel-1A Dual Polarised SAR Data in Udham Singh Nagar (Uttarakhand)

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ABSTRACT

Udham Singh Nagar is one of major rice producing area of Uttarakhand state, and it falls in *Tarai* region. The soils of the region are considered as most fertile land in India and aptly support rice production. Rice is a mainly grown in the rainy season which results in a limited number of cloud-free optical remote sensing images for estimation of rice acreage and its monitoring. Sentinel-1A is a European radar imaging satellite launched in 2014. Sentinel-1A satellite launched as a part of the European Union's Copernicus program which provide Synthetic aperture radar (SAR) data i.e. potentially well suited for rice crop monitoring. It allows observations of different features of earth which are independent of weather conditions and solar illumination. The basic goal behind this study was to apply new generation Sentinel-1A data with dual polarization (VH and VV) to rice cropping system mapping and monitoring. SAR data provides an advantage in Land use-land cover (LULC) classification task because these images are not influenced by cloud and leads to increase in mapping accuracy. In the present paper the potential of SAR application for measuring rice acreage during persistent cloud cover has been demonstrated using Sentinel-1A data of European Space Agency. Data were pre-processed by applying European Space Agency's Sentinel Application Platform (SNAP). The SAR dataset classified with a Support Vector Machine (SVM) algorithm provided in ENVI- 5.1 produced the accurate LULC map, which shows that Udham Singh Nagar covers rice area (108,095 Hectares), followed by forest (140,220 Hectares), water body (15,976 Hectares) and fallow land (5060 Hectares) and lastly built up area (2,586 Hectares) with an overall classification accuracy of 92.88% and a Kappa coefficient of 0.89. This mapping approach provides an advantage of all-weather mapping capability of the radar sensor with the short revisit period of Sentinel-1A satellite. The mapping results represent an important step toward future tasks of retrieval of crop biophysical parameters using SAR data.

Keywords

ENVI, Remote sensing, SAR, Sentinel-1A, SNAP, SVM

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Introduction

Rice is one of the world's major agricultural crops. It is the staple food of more than 50% of the Earth's population (FAO, 2002). Rice is mainly grown in kharif season and accounts

for more than 54 percent of the total area under cereals in Uttarakhand state. Rice is grown in all the 13 districts of the state, but maximum area (33%) is under district Udham Singh Nagar which produces about 48% of the total rice produced annually in the state. For

planning and monitoring purposes there is need of up-to-date information on areas which are under rice cultivation and any changes in the cultivated area is very essential for national political decision-makers and for international trade organizations.

So, remote sensing is one such beneficial technology which provides an advantage for effective land cover mapping at a very large scale for up-to-date areas information, and it can be made more cost-effective by increasing the repeatability of observations (Chilar, 2000; Kuemmerle *et al.*, 2013). In this context, airborne as well as space-borne remote sensing data mainly Synthetic Aperture Radar (SAR) data has shown promising results in crop monitoring and classification with a very high accuracy. Backscatter coefficient (the differential scattering cross section per unit volume for a scattering angle of 180°) of SAR data in different polarizations and frequencies for crop identification and monitoring have been reported (Toan *et al.*, 1989, 1997; Hoekman and Bouman, 1993; Kurosu *et al.*, 1995; Schotten *et al.*, 1995), using polarimetric scattering matrix that contains information about polarization amplitude as well as phase for rice crop characterization and its classification has also been studied (Freeman *et al.*, 1994; Skriver *et al.*, 1999; Lee *et al.*, 2001; Ainsworth *et al.*, 2009; Haldar *et al.*, 2012; Turkar *et al.*, 2012, Panigrahy *et al.*, 2013).

Attempts have been made to establish relationships between polarization signatures of SAR signal to target rice crop properties (Ulaby *et al.*, 1987; Boerner *et al.*, 1987; Wang and Mo, 1990). This study explored the use of the European radar imaging satellite i.e. Sentinel-1A which was launched in 2014 for synergistic land cover mapping by exploiting SAR data, for rice acreage estimation in Udham Singh Nagar district of Uttarakhand. The Sentinel-1A sensor gives SAR images in

both single and dual polarization mode (for detailed descriptions of Sentinel-1A mission see Torres *et al.*, 2012).

The spatial resolution of Sentinel-1A is very high (5 × 20 m in the Interferometric Wide Swath mode), have a large coverage up to 400 km and also good temporal resolution which provide advantage for accurate land cover mapping (Wagner *et al.*, 2012). Sentinel-1A has frequent revisit time which provides a major advantage over previous launched radar missions, and help in mapping and analyzing the agricultural land covers and phenological dynamics in vegetation, simultaneously with the dual polarization capability and rapid product delivery (Torres *et al.*, 2012). The main objective of this study is to give a methodological framework using SAR data for accurate land cover mapping by applying object-based and spectral classification technique.

Materials and Methods

Study area and dataset used

The study area was Udham Singh Nagar district having an area of 2,908 km² and located in Uttarakhand. Geographically, Udham Singh Nagar is situated between 28.9610° N latitude and 79.5154° E longitude. The elevation of this place from mean sea level is around 216 meter. The area lies in “tarai” belt located in foot hills of the Himalayas. The area falls under sub-humid and subtropical zone with three distinct seasons. It has summer season from March to June, a rainy season from July to October and cold winter season from November to February. The location map of the study area along with the satellite image of the place has been shown in Figure 1.

For this study, cross-polarized (VH) & co-polarized (VV) Sentinel-1A data acquired on 9

October 2017 has been used. The attributes of the Sentinel-1A data used in the study have been presented in Table 1. The Sentinel-1A data was downloaded from the ESA Open Access Hub (<https://scihub.copernicus.eu>).

Ground truth data collection

The geographic locations and the field boundaries of land use and land covers (LULC) were recorded by using the GPS based mobile mapping unit. Vector layers of these land use and land cover were made by the use of GPS unit which was in UTM projection and these vector layers contained all the detailed information regarding each sampling unit as an output layer. These layers were used on the geo-referenced images for retrieving accurately training set for each class.

Data pre-processing and processing

Two Sentinel-1A images which cover the entire study area were downloaded from the ESA's Sentinel Scientific Hub (ESA, 2017a). SAR data pre-processing of the Level-1 GRD image was done by using the SNAP (Sentinel Application Platform toolbox) (ESA, 2017b) standard processing methods which were used in the pre-processing of SAR data i.e. calibration, thermal noise removal, mosaicking, resampling to $10 \times 10 \text{ m}^2$ spatial resolution and multilook parametrization for both VV and VH polarization images. For the removal of the speckle effects means the distortions comes in the radar images which are also the characteristic of radar images were remunerated by the use of Refined Lee low-pass filter with a 5×5 kernel, which basically remove the speckle effects by averaging the image and preserving feature edges (Wang *et al.*, 2012).

Radar image backscatter is strongly influenced by the ground surface texture, which gives

very important information for classification tasks, and has been used many times for radar-based land cover mapping. So, for calculating the radar derived texture, a module was used which was given in the SNAP, grey-level co-occurring matrix (GLCM) module (texture variance and texture contrast) for both VV and VH polarization, parameterized with a 5×5 window size and 32 probabilistic quantization levels which results in four different texture images of the Sentinel-1A data (Clerici *et al.*, 2017). And, these six different texture images were then layer stacked into a 6-layers image:

Sentinel-1A VH and VV amplitude images (2)

Sentinel-1A VH and VV, variance texture images (2)

Sentinel-1A VH and VV contrast texture images (2).

A set of land cover classes were taken which are: built up, rice crop, fallow land, water body and forest. The land use and land cover were selected on the basis of various previous studies. An object-based classification was carried out on ENVI-5.1 by using a supervised classification algorithm, Support Vector Machine (SVM) (Borges, 1998). Support Vector Machine Classification (SVM) is a classification system derived from statistical learning theory. It separates the classes with a decision surface that maximizes the margin between the classes. The surface is often called the *optimal hyperplane*, and the data points closest to the hyperplane are called *support vectors*. The support vectors are the critical elements of the training set. Data preprocessing and processing steps are shown in Figure 2.

Results and Discussion

Initially, the training samples of the five classes: built up, rice crop, fallow land, water

body forest were selected and, the SVM classifier was applied which trains and runs on the reduced resolution image and ROIs.

The classifier performs training at the lower-resolution level (instead of at full resolution and applying the results at each level) because retraining at each level provides higher-accuracy results for the resampled imagery. So, the sampling steps should be taken carefully for carrying out this classification.

From the sample values chosen for each class, the algorithm determined the best pair of the Gaussian kernel. The use of the radar stacked layers produce acceptable results with SVM classifier. The classification results obtained from the SVM-classification algorithm applied to the integrated layer stack of Sentinel 1A radar data are given in (accuracy statistics in Table 2), thus we discuss here detailed results

only from this classification approach. The dominant land cover in the study area is forest (140,220 Hectares), followed by rice (108,095 Hectares) then water body (15,976 Hectares) and fallow land (5060 Hectares) and lastly built up (2,586 Hectares).

Following standard accuracy calculation procedures we estimated an overall accuracy of 92.88%, and a Kappa coefficient of 0.89 as given in Table 2. Omission and commission classification errors were found mainly in rice, fallow land, and water body likely due to the high spectral heterogeneity present in the above classes generated and in rice the errors are also due to the large variety of different cultivars and of vegetation types/growth stages, respectively. A detailed confusion matrix of the integrated datasets SVM-classified map, with overall, user and producer class accuracies, is reported in Figure 3.

Fig.1 Location of the study area with the Satellite image

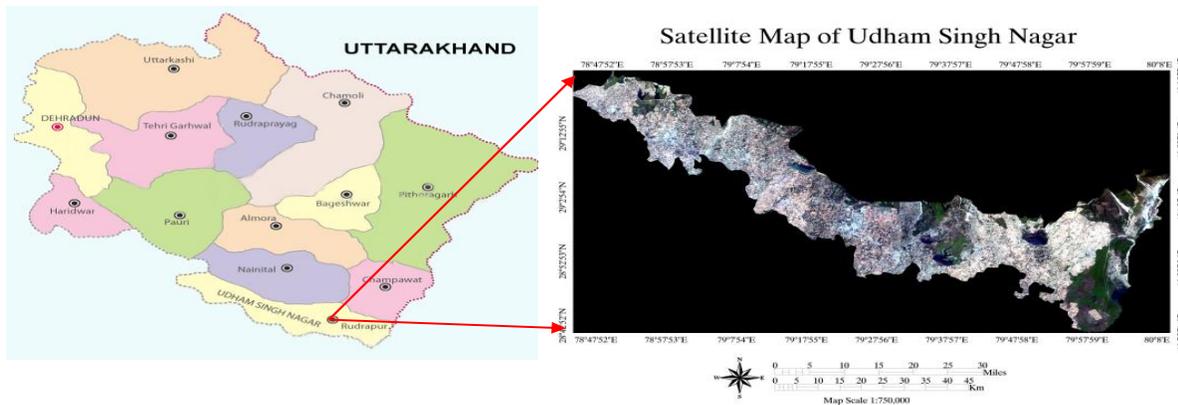


Fig.2 Steps involved in pre-processing and processing

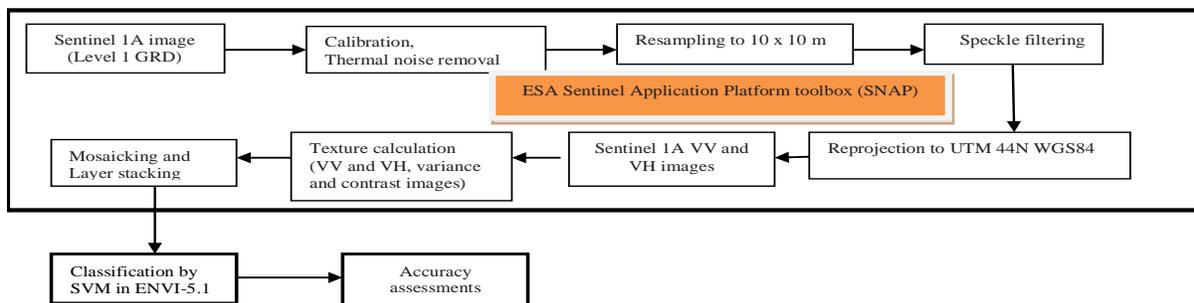


Fig.3 Confusion matrix and classification accuracy measures of the SVM-classified map

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Confusion Matrix: C:\subsets\udham singh nagar_class
Overall Accuracy = (3940/4242) 92.88%
Kappa Coefficient = 0.8995

  Class      Ground Truth (Pixels)
             builtup  rice    fallow land  water body  forest
builtup      981      0        0            0            57
rice          0      984      17           2            0
Fallow land  0       22      13           3            0
water body   0       14      254          782         0
forest       78      0        0            0          1035
Total       1059     1020     284          787         1092

  Class      Ground Truth (Pixels)
             Total
builtup      1038
rice         1003
fallow land   38
water body  1050
forest       1113
Total       4242

  Class      Ground Truth (Percent)
             builtup  rice    fallow land  water body  forest
builtup      92.63      0.00      0.00         0.00         5.22
rice          0.00      96.47      5.99         0.25         0.00
fallow land  0.00      2.16      4.58         0.38         0.00
water body   0.00      1.37      89.44        99.36         0.00
forest       7.37      0.00      0.00         0.00         94.78
Total      100.00     100.00     100.00       100.00       100.00

  Class      Ground Truth (Percent)
             Total
builtup      24.47
rice         23.64
fallow land  0.90
water body  24.75
forest       26.24
Total      100.00
    
```

Class	Commission (Percent)	Omission (Percent)
builtup	5.49	7.37
rice	1.89	3.53
fallow land	65.79	95.42
water body	25.52	0.64
forest	7.01	5.22

Class	Prod. Acc. (Percent)	User Acc. (Percent)
builtup	92.63	94.51
rice	96.47	98.11
fallow land	4.58	34.21
water body	99.36	74.48
forest	94.78	92.99

Table.1 Characteristics of sentinel-1A data

Parameters	Characteristics
Polarization	Dual (VV, VH)
Frequency	5.405 GHz
Wavelength	18 cm
Spatial Resolution (250 km)	5x20meters
Incidence Angle Range	29.1° to 46.0°
Pass	Descending

Table.2 Overall accuracy and kappa index for the SVM

Sentinel-1A radar layer		
	Overall accuracy (%)	Kappa Coeff.
Support Vector Machine	92.88%	0.89

The LULC classification which is carried out by using Sentinel-1A data gives an advantage of retrieving all the information related to the rice crop due to its active sensors, which transmits remotely sensed data continuously even in cloudy and rainy seasons and because this satellite has all weather capability and shorter revisit time period, so it also plays an important role for monitoring of the rice and other crops.

On the basis of the topography of Udham Singh Nagar region, it is significant to note down that in some areas the time of seeding is not the same as specified in the local agricultural calendar.

In order to develop a monitoring system for rice growth more than one SAR image should be taken around the middle rice growing seasons and for this multipolarization SAR data at various frequencies (C, X, L), and a good set of ground truth data are recommended.

The resulting LULC map provides an opportunity for the calculation of above ground biomass and carbon content estimation for each LULC category in the Udham Singh Nagar district.

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