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International Journal For Research in
Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 Issue: XII Month of publication: December 2017

DOI:

www.ijraset.com

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Land Cover Classification Using Sentinel-1 SAR Data

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Abstract: *The role of polarimetric Synthetic Aperture Radar (SAR) data available from various airborne and space borne sensors is increasing in various remote sensing applications which include land use/land cover classification and also change detection of an area over a period of time. The dual polarization (VV & VH) polSAR data of Sentinel-1, a space borne sensor is used in the present study of land use/land cover classification of Visakhapatnam, a fastest developing city in the state of Andhra Pradesh, India. This polSAR data has been collected on October 19th 2014 along the descending orbit over Visakhapatnam area. This data has been pre-processed using the techniques such as calibration, terrain correction and also filtered with a 5x5 kernel with gamma map approach. During the process of terrain correction this polarimetric SAR data has been resampled with a pixel spacing of 20m. Various classification algorithms such as Iso data, K-means (Unsupervised) and Parallelepiped, Mahalanobis, Maximum Likelihood, Minimum Distance, Artificial Neural Net and Support Vector Machine (Supervised) have been implemented for the land use/land cover classification of the study area. The land use/land cover classification has been analyzed with the available individual polarization data VV, VH and also the combination of VV and VH. Post processing of the classification results has been done using the confusion matrix (also known as error matrix) and corresponding overall accuracy and Kappa coefficients of all the classification methods have been calculated. It is observed from the results that the overall accuracy obtained from the combination of VV&VH polarizations increases up to 100% against 80.09% and 96.86% of using individual polarization VV and VH, respectively. It is also observed that overall accuracy and Kappa coefficient of Support Vector Machine classifier are high compared to other classification methods. This analysis makes it clear that dual polar metric Sentinel-1 SAR data can be effectively used for accurate land cover classification, along with other advantages of urban planning and management of developing areas.*

Keywords: *Sentinel-1A, SAR, Support Vector Machines, Land-use/land-cover classification, Accuracy*

I. INTRODUCTION

Land-use/land-cover (LULC) classification has got lot of importance for preparing the maps of developing cities since this information is very useful for many applications such as agriculture (Bargiel 2011), biodiversity (Falcucci 2017), urbanization (Geymen 2008), (Liu H. and weng Q. 2013), natural environment analysis (Ullmann 2014) and hazard assessment (Van der Sande 2003). Today many earth observation satellites are available because of the recent advancement in remote sensing technology enabling the close monitoring of the earth surface. Due to various reasons like population growth, natural calamities, and climatic changes, lot of research is going on for the protection and management of natural resources in many countries. The land cover classification can be done more effectively by efficient utilization of remote sensing data (Friedl 2010). The land-use/land-cover information of any area can be monitored continuously and consistently using the data sets available from Synthetic Aperture Radars (SAR) (Balzter 2015). Moreover, when meteorological conditions are not favorable to acquire optical data, SAR data can be used for land cover classification. In addition to this, cloud-free images will be provided by SAR satellites (Longepe 2011) (Niu 2013), (Balzter 2015). Various Image classification techniques are available to extract the information from the available SAR data sets to identify different types of the land cover with respect to the pixel values of the SAR image. The dual orbit, multi-temporal and fully polarimetric RADARSAT-2 data has been used for obtaining the land cover mapping (Niu 2013) using the intensity information with polarimetric parameters to increase the accuracy of land cover classification.

The overall accuracy obtained with the combination of dual polarization VV and VH data is more (70%) compared to the accuracy obtained with individual polarization data sets. Support Vector Machine (SVM) is a widely used machine learning algorithm in remote sensing applications by ensuring high classification accuracy while using small training data set (Melgani 2004). In this paper the study areas Visakhapatnam city which has more than 3.78 million populations. Rapid industrialization in this city area has significantly increased the population of the city during the last decade. Consequently, some land cover of the study area such as

agriculture and forest were transformed into urban class(Geymen 2008). The previous studies reported that Visakhapatnam suffers from natural disaster and other phenomena due to its geological structure and human activities. In fact, high accuracy is preferred by the planning and development of any urban area to obtain the land cover mapping. In order to support the mapping of land-cover/land-use, up-to-date information is crucial. The main aim of this paper is to analyze the Sentinel-1A SAR data sets for the land cover classification and mapping using amplitude information of dual polarimetric SAR imagery(Abdikan 2015).

A. Study Area

The study area is Visakhapatnam, a smart city in the State of Andhra Pradesh, India. The investigation has been carried out in an area of 621.52 sqkm. The city is head quarters of Visakhapatnam District. The city is located between 17⁰ 10' and 17⁰ 56' N latitude and 83⁰ 08' and 83⁰ 40' E longitude (Fig: 1). It is bounded by Orissa state and Vizianagaram district on North side , East Godavari district towards South, Orissa state towards West and Bay of Bengal towards East .

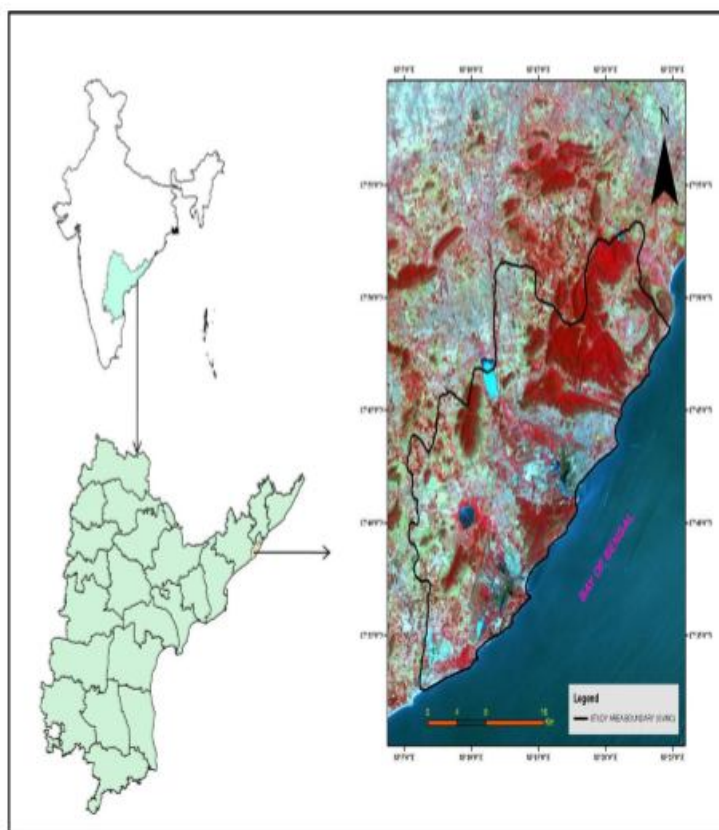


Figure-1 Location Map of the Study Area

B. Data Used

The data used in the present study of land use/land cover classification of Visakhapatnam city has been obtained from the Sentinel-1, a spaceborne sensor launched by the European Space Agency (ESA) in the month of April, 2014. In the present case two data sets of dual polarization SAR imagery VV, VH are supplied by the Sentinel-1 satellite which is operated in C-band. Since Sentinel-1 data is freely available any user can access and obtain the polarimetric SAR data and make use of it for study and research purpose. (Nagler et al., 2015). The Strip Map (SM), Interferometric Wide Swath (IW), Extra Wide Swath (EW) and Wave (WV) are the different data acquisition modes of Sentinel-1 Level-1 Ground Range Detected (GRD) product of Sentinel-1 is used in this paper. SAR data set of Sentinel-1 sensor was collected in October 19th 2014 over Visakhapatnamcity. The Earth ellipsoidal modelis used for multi-looking and as well as projecting this GRD data to the ground range.Figure 2 depicts the composite image of the study area obtained with the dual polarimetric data sets VV, VH andthe combination of both. The specification of the data is given in Table 1.

Specifications	Sentinel-1A data
Acquisition time	October 19 th 2014
Acquisition orbit	Descending
Imaging Mode	IW
Imaging frequency	C-band (5.4GHz)
Polarization	VV-VH
Data product	Level-1 GRD
Resolution mode	20 m (Full resolution)

Table-1. Specifications of Sentinel-1A data

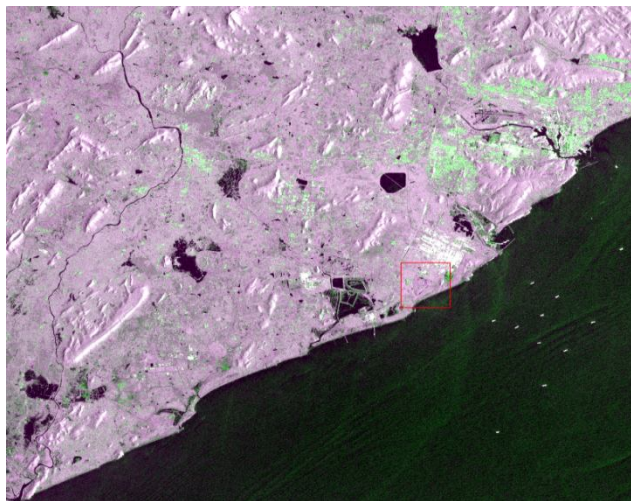


Figure-2 Backscattered Image (R: VH, G: VV, B: VH+VV)

C. Pre-Processing

The Level-1 product of Sentinel-1 GRD data is calibrated, filtered by a 5X5 kernel using gamma map approach and terrain corrected before application. During terrain correction a 25m SRTM-DEM data has been used and the data was re-sampled to a pixel size of 20m ground resolution. The SAR data is converted into backscattering values in terms of decibels (db). Pre-processing was conducted using ESA Sentinel-1 toolbox (S1TBX) in the Sentinel’s Application Platform provided by ESA.

II. RESULTS AND DISCUSSIONS

Various classification methods have been implemented for the land use/land cover classification of the study area which include both unsupervised(Isodata, K-means) and supervised(Parallelepiped, Mahalanobis, Maximum Likelihood, Minimum Distance, Artificial Neural Net and Support Vector Machine) for mapping different land cover types. Since the supervised classification algorithm Support Vector Machine (SVM) is a machine learning algorithm it has been widely used and tested many times in remote sensing in both optical and radar data for image classification **Error! Reference source not found., Error! Reference source not found.** The principle of SVM is to define an optimal hyperplane to maximize margin width by using training subset **Error! Reference source not found.** In the present study, the Radial Basis Function (RBF) is used **Error! Reference source not found.** and optimum parameters were determined as 0.333 and 100 for kernel width and penalty parameter, respectively. Further details of this method could be found in **Error! Reference source not found.** Confusion matrix assessment was applied to compare the accuracy of classified images. For the optimum utilization of available dual polarimetric SAR data of Sentinel-1 individual polarization data sets of VV , VH along with combination of both VV & VH cases were considered and various classification methods have been implemented to obtain the better accuracy results.

S.no	Data sets
1	VV
2	VH

3	(VV+VH)
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Table-2. Datasets for land cover classification

In the present study three data sets of different polarizations were defined for image classification, and impact of variables was evaluated. First, each polarimetric data was classified as single variable and the results show that VHpolarimetry has slightly higher accuracy than VVpolarimetry. The accuracy for VH, VV and (VH&VV) images were found 96.86%, 80.09% and 100% respectively. When the combined dual polarization SAR data (VV&VH) is used for classification of the study area the resulting overall accuracy has been increased compared to the accuracy obtained with the individual polarization data sets of VV and VH. The images obtained after the classification is done corresponding to different polarization data sets VV, VH and combination of VV&VH are shown in Figure 3, Figure 4 and Figure 5 respectively. The water class is extracted clearly even when the single polarization data set(VV) is used as shown in the figure 1 where as the urban class could not be extracted in this case. It is also observed that some misclassification can be seen near the hilly parts of the study area.

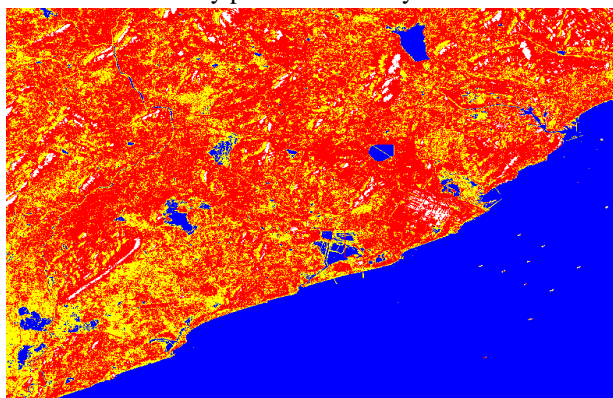


Figure-3 Support Vector Machine Classified Image only VH
(Blue: Water, White: Urban, Red: Vegetation and Yellow: Barsoil)

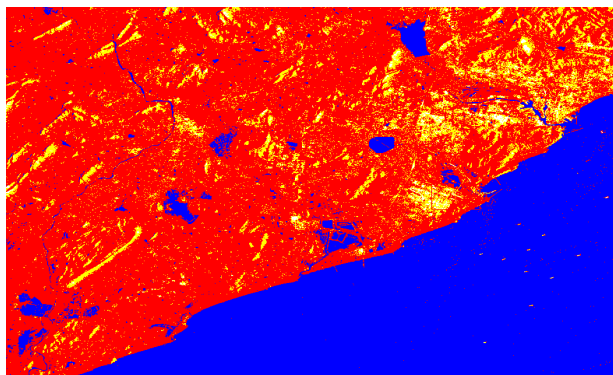


Figure-4 Support Vector Machine Classified Image only VV
(Blue: Water, White: Urban, Red: Vegetation and Yellow: Barsoil)

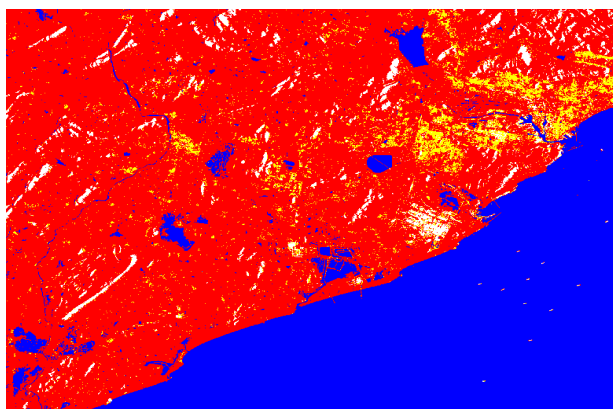


Figure-4 Support Vector Machine Classified Image (VH+VV)
(Blue: Water, White: Urban, Red: Vegetation and Yellow: Bare soil)

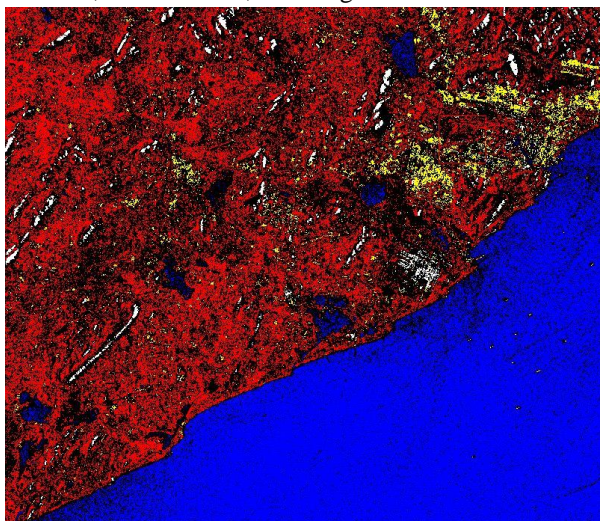


Figure-5 Parallelepiped Classified Image
(Blue: Water, White: Urban, Red: Vegetation and Yellow: Bare soil)

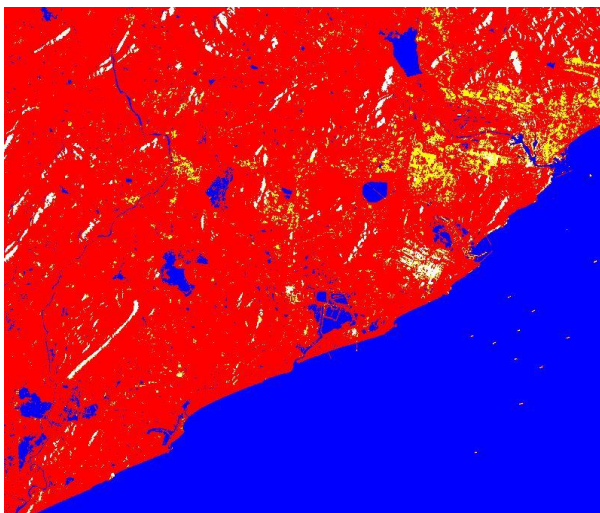


Figure-5 Minimum Distance Classified Image
(Blue: Water, White: Urban, Red: Vegetation and Yellow: Bare soil)

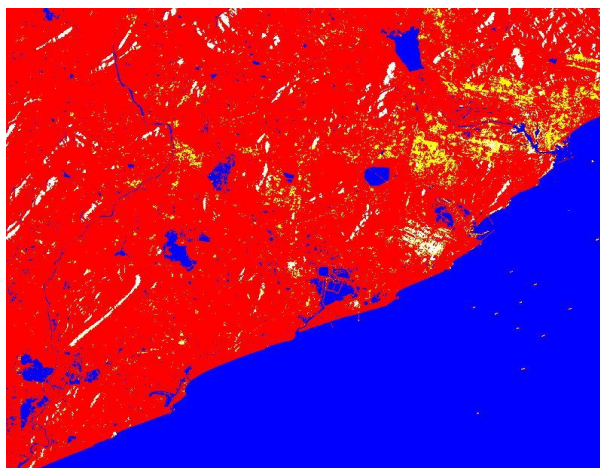


Figure-6 Mahalanobis Distance Classified Image
(Blue: Water, White: Urban, Red: Vegetation and Yellow: Bare soil)

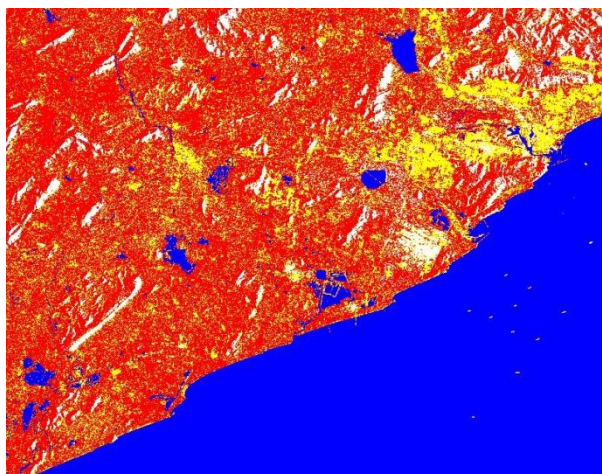


Figure-7 Maximum Likelihood Classified Image
(Blue: Water, White: Urban, Red: Vegetation and Yellow: Bare soil)

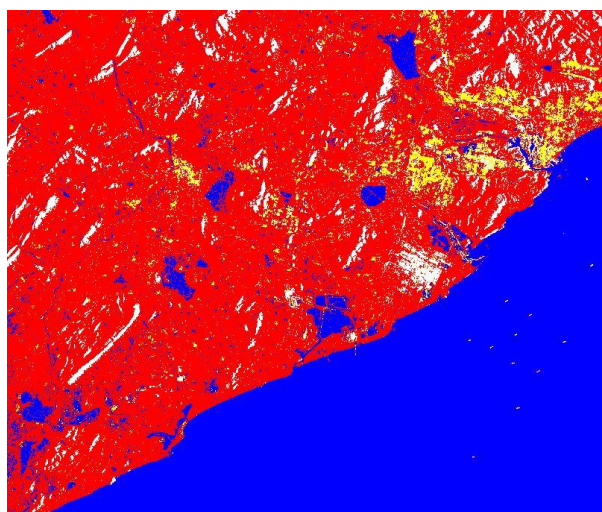


Figure-7 Artificial Neural Net Classified Image
(Blue: Water, White: Urban, Red: Vegetation and Yellow: Bare soil)

A. Accuracy Assessment

Classification	Overall Accuracy	Kappa Coefficient
Unsupervised Classification		
Isodata	71.645	0.622
K-Mean	73.160	0.642
Supervised Classification		
Parallelepiped	90.045	0.858
Minimum Distance	90.087	0.861
Mahalanobis	91.388	0.879
Maximum Likelihood	98.950	0.985
Artificial Neural Net	99.257	0.990
Support Vector Machine VH	96.862	0.958
Support Vector Machine VV	80.087	0.735

Support Vector Machine (VH+VV)	100.000	1.000
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Table-3. Accuracy Assessment for various classifications

III. CONCLUSIONS

In this study, the performance of Sentinel-1 SAR data sets was evaluated. It is aimed to figure out the potential of using only SAR data sets over a complex megacity for land cover classification. In order to increase the accuracy of image classification results, different variables are created by dual polarimetric data and different scenarios were also tested. The experimental results indicate that different scenarios provide different results depending upon the corresponding variables. Using combined imagery (VV+VH) as a third variable into the classification resulted in higher accuracy than individual polarization data imagery. The revisit time of Sentinel-1B is 6 days of systematic image acquisition. Hence it provides the data sets frequently for the analysis of land cover classification. The results indicate that dual polarized IW Sentinel-1A is best suited for rapid land cover classification using SAR data sets. The results obtained in this study may be useful as a reference for further analysis of Sentinel-1 data of other cities.

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