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Evaluation of full-polarimetric parameters for vegetation monitoring in *rabi* (winter) season

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ABSTRACT

Remote sensing data particularly Polarimetric Synthetic Aperture Radar (Pol SAR) data has shown promising results in crop monitoring and classification with reasonably high accuracy in tropical countries like India. Our study explores the use polarimetric SAR data for crop discrimination by evaluating different polarimetric parameters and various decomposition techniques using single date fine quad-pol C-band RADARSAT-2 dataset over heterogeneous agricultural area of Mehsana district of Gujarat state in India. Vegetation parameter, Radar Vegetation Index (RVI) and five decomposition techniques (e.g. H/A/α, Freeman-2, Freeman-3, Van Zyl-3 and Krogager) based on incoherent and coherent decompositions were selected to generate input images of classification. RVI shows good correlation with the crop stage at higher biomass with high value of RVI and with urban and water body with lower values of RVI respectively. H/A/α and its combinations i.e. (H-A) and (1-H)(1-A) show good results for discriminating land cover with different scattering mechanisms. Freeman-2, Freeman-3, Van Zyl-3 and Krogager are also evaluated for classification capability between various land covers and different crop types at different phenological stages. In 3-component decompositions, Freeman gives better results compared to other decomposition techniques for discriminating agricultural crops and natural vegetation. VanZyl decomposition overestimates surface component for agricultural crops and vegetation compared to Freeman 3-component decomposition. Krogager decomposition gives better seperability for man-made targets. The limitations of optical data for discrimination of crops based on biophysical parameters at various crop stages with similar spectral signature can be overcome by even single date full polarimetric SAR data with different decomposition techniques.

1. Introduction

Polarimetric Synthetic Aperture Radar (Pol SAR) systems have become highly fruitful, thanks to their wide area coverage and day and night and all-weather capabilities. Several polarimetric SARs have been flown over the last few decades with a variety of polarimetric SAR imaging modes; such as linear, single and dual-pol modes. Other alternative modes, such as hybrid and compact dual-pol, have also been recently in use. More sophisticated ones are full polarimetric modes (Shirvany et al., 2013). The multi-polarized configurations provide more information related to crop structure and condition. The phase, polarization phase difference and polarimetric parameters do help in understanding the different scattering mechanisms from different terrestrial features in general and crops in particular (McNairn et al., 2010; Haldar et al. 2012, 2016; Ramana et al., 2014; Srikanth et al., 2016). RADARSAT-2 is a Canadian C-band SAR satellite, and a major data source for commercial applications and remote sensing science, providing valuable information for different application areas including agriculture, forestry, oceanography, coastal and marine surveillance and ice monitoring (Singhroy and Charbonneau, 2014, Van der, 2014, Scheuchl et al., 2014). It supports right- and left-look imaging and provides both full-pol and dual-pol data. SAR multidate datasets with dual or hybrid polarimetry are used for agricultural study. Reflected or emitted signals of backscattered SAR waves provide information about the physical properties of the objects for various applications (Tetuko et al., 2003; Husnul et al., 2017). Several authors have reported the use of SAR backscatter coefficient (σ^0) in different polarizations and frequencies for crop identification and monitoring (Chakraborty et al., 2005; Kurosu and Fujita,

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1995). Others have reported about polarimetric scattering matrix that contains information about amplitude as well as phase for crop characterization and classification (Freeman et al., 1994; Lee et al., 2001; Ainsworth et al, 2009; Haldar et al. 2012; Turkar et al., 2012). Quad-pol data have full polarization (HH, HV, VH, and VV) and also phase information which is found to be very useful in agricultural study. The polarimetric target decomposition theorems express the average scattering mechanism as a sum of individual and independent scattering mechanisms (Cloude, 2010). Coherent decomposition, which deals with the scattering matrix and incoherent decomposition, which deals with coherency (T3) or covariance (C3) matrices (Pottier et al., 2007) are two polarimetic decomposition techniques. Pauli and Krogager (sphere, diplane, helix – SDH) are the well known Coherent Target Decomposition methods and the incoherent Target Decomposition are Freeman (Model based decompositions), van Zyl (eigenvector or eigenvalues analysis) and Yamaguchi. (van Zyl, 1989; Freeman and Durden, 1992, 1998; Yamaguchi et al., 2005, 2006; Alberga et al., 2008; Lee and Pottier, 2009a, 2009b). Incoherent decompositions divided into two groups in which the first group is eigenvalue decomposition (Pottier, 1994; Cloude and Pottier 1996a,b, 1997), where entropy (H), anisotropy (A), and alpha angle (α) are decomposition parameters. The second group is model-based decomposition proposed by (Freeman and Durden, 1998). In this decomposition technique, the covariance matrix was represented as the contribution of three scattering mechanisms – single bounce scattering, double bounce scattering, and volume scattering. Time series polarimetric Radarsat datasets have been used for crop biomass and phenology monitoring (Haldar et al., 2016, Srikanth et al., 2016). The objective of this study was to explore the use of full-pol data to observe how best a single date polarimetric data can aid in agriculture for crop discrimination and separability of crops at a particular stage (coinciding with the medium stage) in their life cycle/phenology using signature study of different land cover for different polarimetric decomposition parameters at the time of non availability of time series data.

2. Study area & dataset

Mehsana district (23.60° N, 72.39° E) of Gujarat state in India was selected for the study. The study area majorly comprises of agricultural land, surrounded by natural vegetation and scrub lands, village clusters and few water bodies with one big canal (Fig. 1). This region is selected for the study due to variability in crop type and crop phenological stages within a smaller area. Crops grown in *rabi* (winter) season in this area are wheat, mustard, cotton, pearlmillet (*bajra*) and castor. Minor crops like spices are grown in certain pockets. Other land covers like *kikar*/natural vegetation and orchards are also found in the same study area. Full polarimetric RADARSAT-2 fine quad-pol (FQ-21) (HH, HV, VH, VV) satellite data was acquired at 40° incidence angle on 23rd January 2014, which coincides with winter crop season in Gujarat. Central co-ordinate at 23.5233° N and 72.2402° E with grid of 25 km × 25 km around was selected as study area. In-situ field information for different land covers were also collected synchronous to satellite pass.

3. Methodology

3.1. Ground data collection

Ground truth data were collected by field survey of the study area synchronous to satellite data acquisition date. Geographical

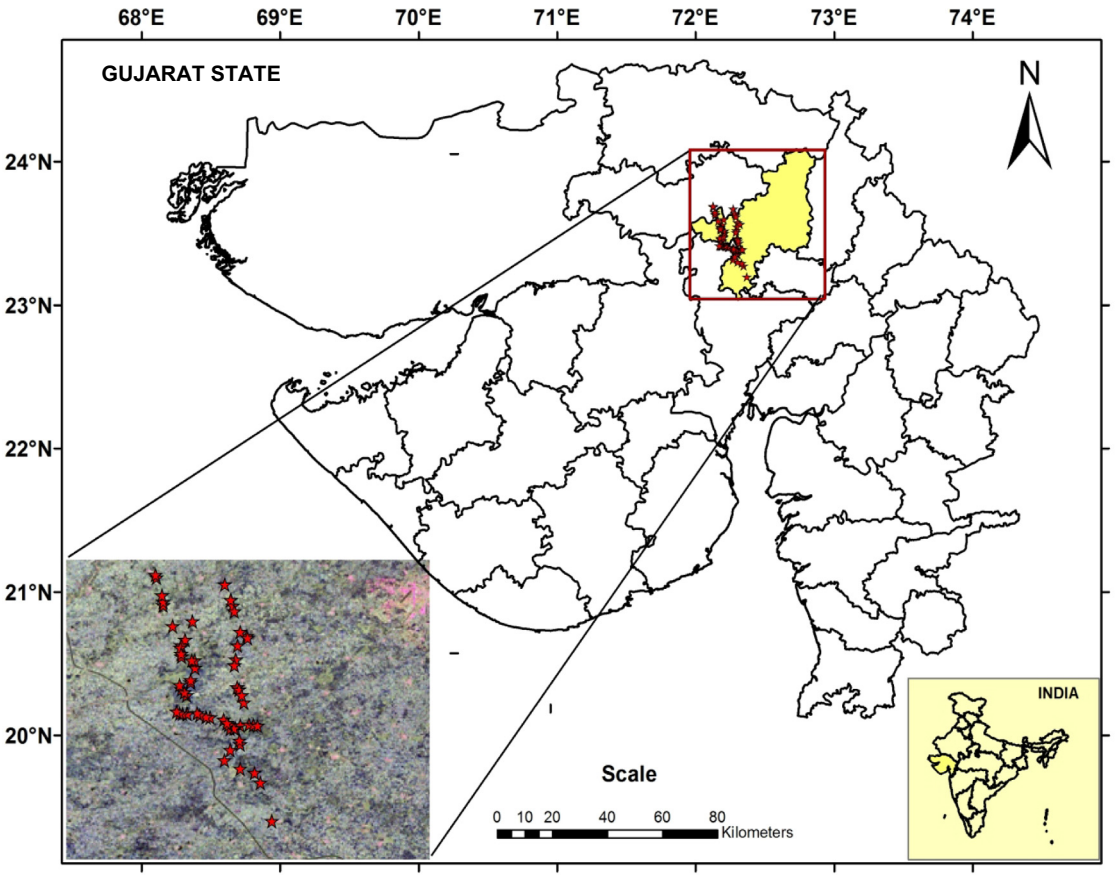

Fig. 1. Map of study area with ground data points and RADARSAT-2 Pauli RGB image.