3-D STRUCTURE OF INDIAN FORESTS – PERSPECTIVES FROM EXPERIMENTS ON THE FIRST FULLY-POLARIMETRIC TANDEM-X TOMOGRAMS

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ABSTRACT:

This paper provides a first hand view of the 3-D structure of the forests when viewed by X-band SAR data. Tomograms are generated using multi-polarimetric space-borne TerraSAR-X/TanDEM-X acquisitions and analysed over a multi-species forest range. The paper analysed these generated tomograms and puts forth-interesting observations of these unique forest species. The high- and low-canopy density plantations provide unique tomograms and vertical structure profiles where the effect of varying extinction is observed in X-band. Further, the scattering powers are shown relative to their backscatter powers. In-depth analysis in currently underway and would be reported in future.

1. INTRODUCTION

TanDEM-X fully-polarimetric acquisitions have been shown to have sensitivity to forest bio-physical parameters over various forest test sites globally (Unmesh Khati, Singh, and Ferro-Famil 2017; Kugler et al. 2014; Krieger et al. 2007). SAR tomography is an advanced SAR processing technique which utilizes multiple SAR acquisitions for estimation of 3-D structure of the forest (Reigber and Moreira 2000; Ferro-Famil, Huang, and Reigber 2012; Tebaldini 2010; Unmesh Khati, Ferro-Famil, and Singh 2017). Globally SAR tomography has been demonstrated using airborne SAR data over forests. However, space-borne SAR data has limited applicability for 3-D structure estimation due to limited acquisitions, temporal gap and low variance of baselines (Lombardini and Cai 2014; Lavalle and Hensley 2015). The present research work is an extension of concerted efforts to utilize multiple TanDEM-X acquisitions for generation of the first fully-polarimetric space-borne X-band SAR tomogram over a forest range (Unmesh Khati, Ferro-Famil, and Singh 2017; Unmesh Khati, Singh, and Ferro-Famil 2017; Unmesh Khati and Singh 2015; U. Khati, Singh, and Kumar 2018). The initial research work focused on evaluating the TanDEM-X pursuit monostatic acquisitions for estimation of forest height and forest above-ground biomass (AGB). Results showed surprisingly accurate forest height estimates over multiple forest test sites in India. The AGB estimation was accurate for forest ranges up to 150 Mg/ha

2. BRIEF METHODOLOGY

For tomography study, the Haldwani forest range was selected as a suitable test site due to known forest management practices, distinct species and relatively flat topography. Subsequently, 18 fully-polarimetric TerraSAR-X/TanDEM-X scenes were co-registered, phase calibrated and focused using a Capon beamformer. Various issues such as low SNR of TanDEM-X, especially at cross-polarized channels, decorrelation and identification of sources of decorrelation are addressed and corrected for. With a well-calibrated data stack, various experiments and validations are carried out:

3. RESULTS

3.1 3-D structure of the forest

With generation of tomograms, the vertical structure of various forest field plots were generated and validated with field observations. Field work carried out in 2015 and 2017 were utilized. One such tomogram is shown in Figure 1. In this figure, the tomograms generated in 5 polarizations – HH, HV, VV, HH+VV and HH-VV are shown. The red dotted line shows the extent of the field validation plot carried out in November of 2015. The field photograph captured during the field survey is shown in Fig. 1 (b). The 3-D structure in the form of vertical scattering profile at the field plot location are shown in Fig. 1 (c). These vertical profiles are shown again in all 5 polarizations along with location of the ground (blue line) and H_{100} height of the plot (black dotted line). It is interesting to note the following:

a. Bare ground or grassland surrounding the Teak plot are accurately estimated and follow the ground height (MSL) shown by the black line in Fig. 1(a)
b. VV-pol signals penetrate further than HH-pol since they interact more with the trunks of the forest while HV-pol tomogram is noisy due to low SNR of TanDEM-X
c. The surface scattering dominates HH+VV tomogram as expected since most of the scattering occurs from the top of the canopy
d. Vertical profiles in Fig. 1(c) show dominant scattering (peak power) along the canopy rather than at the top of the canopy. This is observed in the field plots where the teak canopy is spread through.
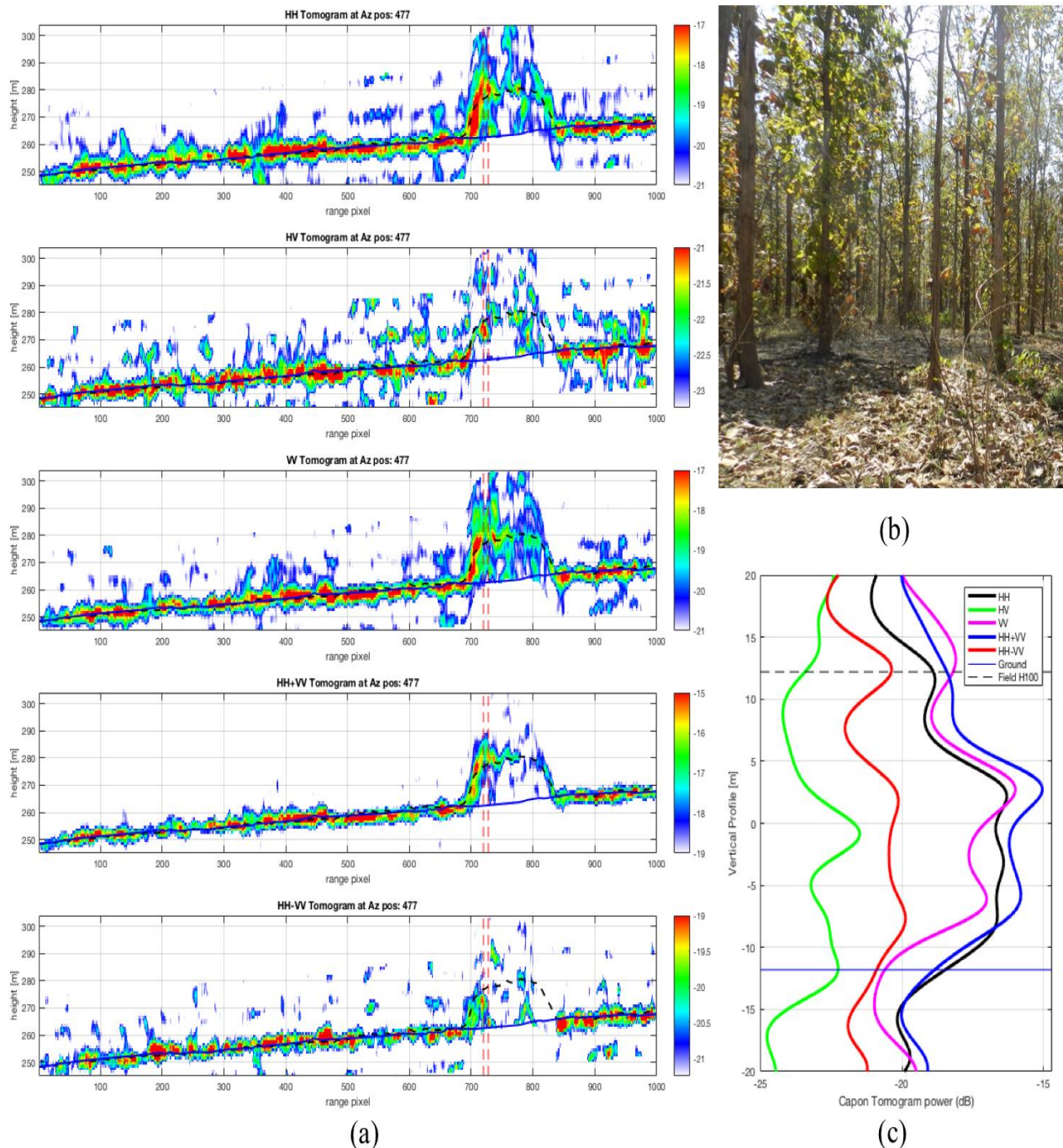
Figure 1 (a) Tomograms in 5 polarizations - HH,HV, VV, HH+VV and HH-VV over a Teak plantation in Haldwani forest range. Also shown are the (b) Field photograph captured in November 2015 and (c) the vertical profile of the field plot in the 5 polarizations. The legend describes the colours.

4. CONCLUSIONS

The present research work is the first attempt to utilize TanDEM-X acquisitions for 3-D structure estimation of tropical forests. Some work has been shown for Tomography over urban areas and boreal forests using single-pol data. However, the variability of the polarimetric signature through the forest vertical structure has not been demonstrated at X-band using space-borne SAR data. This novel experiment successfully estimates the 3-D forest structure and shows a surprising penetration capability of the X-band microwaves through the test site. This is expected to be a function of the canopy gaps and row plantation of this managed forest test site. The relative power of the vertical profiles at different polarizations depicts the actual scattering power centre and attenuation through the canopy. The 3-D structure of multiple field plot locations are currently being analysed to estimate the forest stand height and forest AGB. Validation of these would be carried out and presented along with extensive analysis.

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