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Characterization of Mango Orchard Biophysical Parameters using NovaSAR-1 S-Band data

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Abstract

This study evaluates the ability of S-band SAR data to characterize the biophysical parameters of Mango orchards. The observations from the correlation matrix of NovaSAR-1 parameters and the biophysical parameters indicate that height had the strongest correlation with VV (-0.40) in comparison to the other biophysical parameters. Based on the testing of models, MLR (Multiple Linear Regression) yielded the best RMSE (0.47m) and MAE (0.68m) in the estimation of height with the parameter's Co-pol index and HH backscatter. In the case of DBH, RFR (Random Forest Regression) gave the highest RMSE (0.23m) and MAE (0.05m) with HH and co-pol index. A comparison between the VV backscatter using S-band and C-band data (obtained from Sentinel-1) was also carried out for the mango orchard with S-band data having a higher dynamic range than C-band data.

1. Introduction

Generation of accurate above ground biomass maps of trees, depends on the structure of trees. Biophysical characteristics of trees such as height and DBH (Diameter at Breast Height) aid in the understanding the structure of the tree [1] [2]. Mango is one of the important horticultural crops of India [3] and it is important to understand the structural characteristics of the trees for better orchard management. The traditional method of biophysical parameter estimation involves the measurement of these parameters manually consuming a lot of time and effort [4]. Estimation of these parameters through remote sensing is highly advantageous due to coverage of large area by satellite data. Biophysical parameters have been estimated using optical[2], LIDAR[5] and SAR[6] data.

Most of the biophysical parameter estimation of trees has been carried out using SAR P (UHF), L and C [1], [7] bands. S band data has not yet been explored for the estimation of biophysical parameters of the trees. S- band lies between low (C) and high frequency bands (L, P). It is speculated that S band data has the ability to overcome the issues that arise in low and high frequency bands [8]. Therefore, to fill this existing research gap, this study is a novel attempt to evaluate the suitability of NovaSAR-1 S band data for the estimation of biophysical parameters. This study has three objectives; 1. To understand the relationship of the biophysical parameters with NovaSAR1 data; 2. To estimate Height and DBH using NovaSAR-1 data and regression models; 3. To understand the difference in the backscatter values of C and S band data by comparing the two datasets. The results of this study would aide in the estimation of biomass and help determine the usefulness of S band data for biophysical parameter estimation. With the establishment of meaningful relationships between the biophysical parameters and SAR data obtained from satellites, field surveys of Mango trees can be carried out quickly with lesser cost and manpower.

2. Study Area and the Dataset used

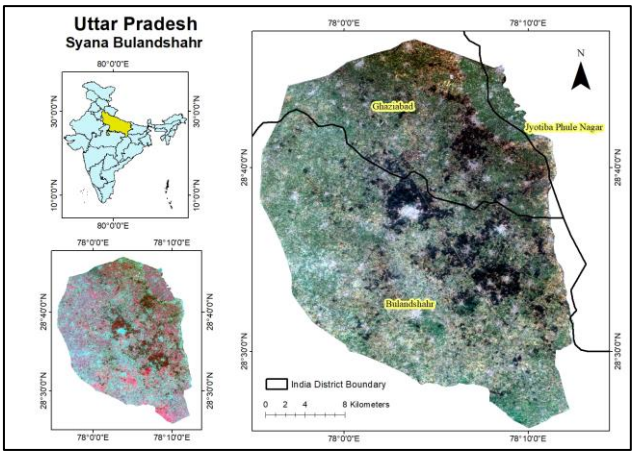

Figure 1. Map of the Study Area

This study has been carried out in the mango orchards of Syana a sub district of Bulandshahr, Uttar Pradesh. The region under study was located at 28° 37' 36.74" N, 78° 3' 38.65"E; with an area of 756.237 Km^2. Syana lies in the main mango producing belt of the country and is famous for Langra, Chausa and Dusheri [9]. Field data pertaining to height, DBH, canopy radius and leaf moisture content was collected for comparison with NovaSAR-1 data backscatter. Medium aged mango trees (15 to 30yrs) were considered in this study.

The NovaSar-1 satellite, developed by SSTL (Surrey Satellite Technology Limited, UK) operates at a frequency of 3.2 GHz with a wavelength of 9.4 cm. The satellite was launched on 16th September 2018 using PSLV C42 from Satish Dhavan Space Centre (SDSC). The satellite

provides images in single, dual and tri-pol modes with combination of VV, VH, HH and HV [10]. The satellite has a temporal resolution of 14 days [11] Dual-pol GRD (Ground Range Detected) data in the polarisations VV, HH was utilised in the estimation of the biophysical parameters. Sentinel-1 data set from Google Earth Engine was used for comparison of back scatter values for mango orchards[12].

3. Methodology

3.1 Data Collection

Field data was collected from 22nd February to 25th February 2022 in Syana, synchronous to the Nova-SAR-1 pass on 23rd February 2022. During the field survey, the geographical location of the orchards, height and DBH was collected. Height of the trees was measured using Nickon Forestry Pro laser [13]. DBH of the trees was measured in accordance to the methodology provided by [4]. Along with DBH and height, other parameters such as canopy radius and leaf moisture were also measured. In the field visit, 77 points of mango orchards were collected.

3.2 Data Pre-Processing

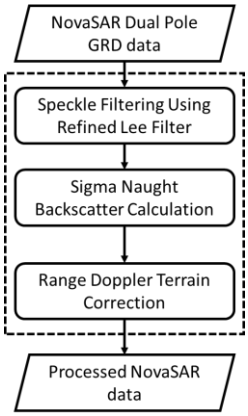

Figure 2. Flowchart for methodology used for pre-processing of Nova SAR-1

Nova SAR-1 dataset downloaded from Bhoonidhi portal, was processed using the SNAP software. Speckle filtering was carried out using the Refined Lee Filter. In order to carry out the calibration of the dataset, following equation was used based on literature [8] [14] The calibration constant was obtained from metadata of the dataset.

$$\sigma_0 = 10*\log_{10}(DN^2) - K_{dB} \quad (1).$$
$$K_{dB} = 10\log_{10}(K)$$
$$\therefore \sigma_0 = 10*\log_{10}(DN^2/K)$$

Where DN: Amplitude data

K: Calibration Constant (Obtained from Metadata)

After calibrating the dataset, range doppler terrain correction was carried out.

3.3 Regression of the parameters

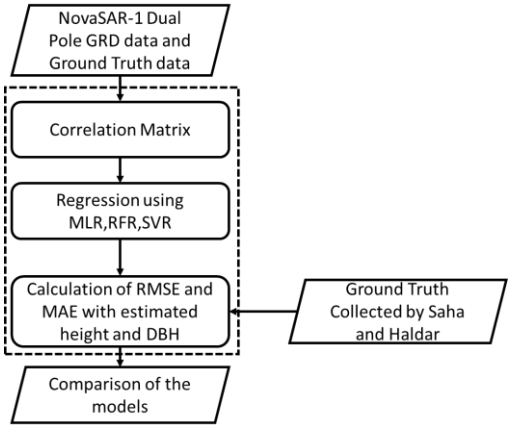

Figure 3. Flowchart for methodology used for pre-processing of Nova SAR-1

The relationship between the backscatter and field parameters (Ground Truth) was evaluated using the correlation matrix. Using the canopy radius readings, canopy area and circumference were also derived. The dataset consisting of height and DBH values was utilized for carrying out the regression using three algorithms; MLR [15], SVR (Support Vector Regression) [16] and RFR [17]. Based on the preference of DBH and height for the estimation of biomass over other biophysical parameters mentioned in this survey, it was decided to build regression models using DBH and height [4] [18]. Regression was carried out using the sklearn library available in python [19]. Remote sensing parameters VV and HH from NovaSAR- 1 were used for estimating height and DBH. Using VV and HH, Co-pol index was also calculated and used for regression [20],[21].

$$Co - Pol = \frac{\sigma_{hh}}{\sigma_{vv}} \quad (2)$$

Where, $\sigma_{hh,}\sigma_{vv}$ are back scatter coefficients in dB

Regression was first carried out using all the SAR parameters i.e. VV, HH and co-pol ratio. The regression models were run again using HH and co-pol index to ascertain the importance of VV in the estimation of DBH and height. The accuracy of the models that predicted height and DBH values was evaluated by estimating RMSE and MAE. The ground truth collected by [22] was used as testing data. The outcomes of the accuracy assessment were compared to determine the best regression model suitable for the estimation of height and DBH.

4. Results

4.1 Relation of Biophysical parameters with S-band data

	VV	HH	CoPole	DBH	Height	Canopy Radius	Canopy Circumference	Canopy Area	Moisture
VV	1.00								
HH	0.60	1.00							
CoPole	-0.57	0.31	1.00						
DBH	0.05	0.07	0.00	1.00					
Height	-0.40	-0.39	0.06	0.17	1.00				
Canopy Radius	-0.25	-0.09	0.18	0.32	0.39	1.00			
Canopy Circumference	-0.25	-0.09	0.18	0.32	0.39	1.00	1.00		
Canopy Area	-0.25	-0.08	0.19	0.33	0.38	1.00	1.00	1.00	
Leaf Moisture	0.05	-0.09	-0.16	-0.09	0.14	0.25	0.25	0.24	1.00

Figure 4. Relation between Nova SAR-1 and biophysical parameters

The strongest relation is observed between VV and height (Refer to Figure 4). The correlation of DBH is low with SAR parameters. The reason for this could be the low incidence angle of the NovaSAR-1 sensor. The low incidence angle penetrates the mango orchard canopy too much to pick up DBH properly. This point is also supported by the correlation values of the canopy radius, area and circumference. All the three parameters have a lower negative correlation coefficient (-0.25) in comparison to height (-0.40). Upon comparing VV, HH and the co-pol index, it is observed that the correlation of VV and co-pol index is higher than HH for the biophysical parameters. Amongst all the biophysical parameters observed, leaf moisture has the lowest correlation values with the SAR parameters. The low relationship of leaf moisture with S-band data could be due to the high penetration of the mango tree canopy.

4.2 Regression Model suitable for the estimation of DBH and Height

Table 1. Comparison of regression models used in the estimation of DBH and Height

Parameters	MLR		RFR		SVR	
	RMSE (m)	MAE (m)	RMSE (m)	MAE (m)	RMSE (m)	MAE (m)
Estimation of Height						
HH,VV,CoPole	0.73	0.54	0.78	0.61	0.80	0.65
HH,CoPole	0.68	0.47	0.83	0.69	0.77	0.60
Estimation of DBH						
HH,VV,CoPole	0.24	0.06	0.25	0.06	0.27	0.07
HH,CoPole	0.24	0.06	0.23	0.05	0.24	0.06

Amongst the three models tested for the estimation of height and DBH, MLR was found to have the least MAE and RMSE (Refer to Table 1). Using all the three SAR parameters i.e., VV, HH and the co-pol ratio gave better results compared to the combination of HH and co-pol ratio. These results indicate that VV is a major component in the estimation of height. In the case of DBH estimation (Refer to Table 1) using all the SAR parameters, MLR gave the least error values. While estimating DBH using HH and co-pol ratio, RFR was found to be slightly better in comparison to MLR and SVR. The removal of VV from SAR parameters did not affect the accuracy of the models indicating that it is not an important parameter for DBH estimation.

4.3 Comparison of S-Band and C-band data Backscatter values for Mango Orchards

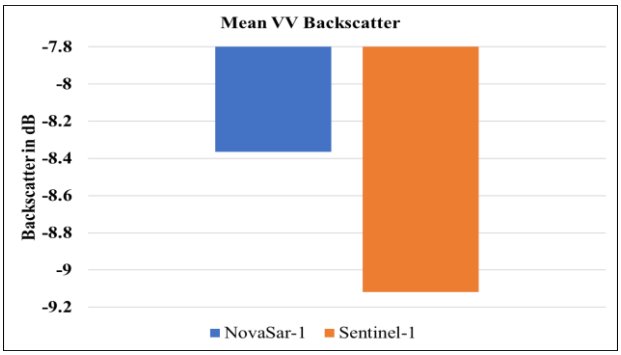

Figure 5. Comparison of VV backscatter values for Mango Orchards using NovaSAR-1 and Sentinel-1

Since Sentinel-1 and NovaSAR-1 have different incidence angles; 21.6º-46º [23] and 16º – 32.2º[24] respectively a direct comparison of the values cannot be made. The comparison made in this study is solely based on the capability of the C and S-band data to highlight the features of Mango orchards. Figure 5 clearly indicates the difference in the backscatter values obtained using S and C band data. The dynamic range of S-band data is higher in comparison to C-band data. This indicates the suitability of S-band dataset for analyzing mango orchards.

5. Conclusion

This study is a novel attempt to characterize the biophysical parameters of mango orchards using S-band data. The results have indicated that height has the strongest relation with NovaSAR-1 data followed by canopy radius and its derivatives. Leaf moisture content and DBH did not exhibit strong relationship with NovaSAR-1 parameters. This behavior of biophysical parameters to NovaSAR-1 data could be attributed to the high angle of incidence of the sensor leading to high penetration of the canopy. While comparing the regression models suitable for the estimation of height and DBH, the performance of MLR superseded SVR and RFR in almost all the cases. RFR performed better for the estimation of DBH using HH and co-pol ratio. VV was found to be an essential component in the estimation of height. On the other hand, all the three SAR parameters tested had equal weightage for estimation of DBH. Based on the correlation matrix and the outcome of regression models it can be concluded that NovaSAR-1 S-band data is suitable for the estimation of height of mango orchards. SAR based DBH and height will be useful for tree growth and biomass monitoring. A comparison of the C and S-band data has indicated that S-band data has a higher dynamic range in comparison to C-band data and is therefore suitable for studying mango orchards. Based on this study, the applications of NovaSAR-1 data for orchards and forest monitoring can be explored.

6. Acknowledgements

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