APPRAISAL OF DUAL POLARIMETRIC RADAR VEGETATION INDEX IN FIRST ORDER MICROWAVE SCATTERING ALGORITHM USING SENTINEL - 1A (C - BAND) AND ALOS - 2 (L - BAND) SAR DATA

7.1 INTRODUCTION

Crop biophysical parameters is key parameter in terrestrial ecosystem and play vital role in the direct exchange of substance and energy between the atmosphere and Earth surface (Macelloni et al. 2001; Jones et al. 2001). Therefore, the study of biophysical growth behavior is important due to its tremendous application (viz. agrometeorological and production forecasting). Nowadays, the remote sensing techniques play vital role to explore the Earth surfaces such as crop and soil moisture monitoring at global scale. In the recent past, the ample research has been carried out to monitoring crop growth variables and soil moisture using semi-empirical, empirical and physical algorithms (Ferrazzoli et al. 1997; Paloscia et al 2013). The optical remote sensing technology and satellite data were greatly adopted in several operational frameworks (e.g., MODIS vegetation products, PROBA - V and Landsat - 8), useful acquisitions by this type of satellite sensors are restricted to nearly cloud-free conditions and less contaminated pixel values. In this context, synthetic aperture radar (SAR) data are more useful for vegetation and soil applications due to the ability of SAR sensors to monitor under acquisition of day-night capability and all-weather conditions (Mattia et al. 2003; Kim et al. 2011). Also, the SAR electromagnetic signals are sensitivity to the dielectric and geometrical properties of crops and soil.

Various optical indices-based vegetation descriptors and some radar vegetation index (RVI) were developed for the sensitivity of crop monitoring and their retrieval of growth variables using microwave scattering algorithms. The radar vegetation index (ratio of $\sigma_{VV}^{0}/\sigma_{VH}^{0}$) was used for crop classification, phenology estimation and vegetation characterization for the various crops (Veloso et al., 2017; Vreugdenhil et al., 2018; Khabbazan et al., 2019).

Cheng et al. (2018) incorporated the degree of polarization (m) of electromagnetic polarized waves for the computation of polarimetric radar vegetation index (PRVI) using quad-polarization (HH +VV + HV + VH) SAR data. They considered the crop canopy as a depolarizing media for changing the electric vector polarization state either H to V or V to H. Meanwhile, the depolarized part of scattering was calculated by subtracting the degree of polarization from unity (i.e., $(1-m)$). Subsequently, multiplying it with the cross-polarization backscattering intensity (σ_{HV}^{0} (dB) for the develop PRVI. This developed PRVI was greatly correlated with the crop growth variables (R^2 = 0.75) than RVI (R^2 = 0.50). However, the cross polarization may be responsible to show the backscattering saturation and falsely show the high value of backscattering echoes even when crop canopy is not developed (McNairn et al. 2018; Fikriyah et al. 2019). Therefore, an alternative approach would be developed for the study of the dominant scattering component (the eigenvalue spectrum of the covariance scattering matrix) while calculating the polarized components of vegetation. Periasamy (2018) developed the dual polarization SAR vegetation Index (DPSVI) by considering the physical scattering behaviour of vegetation, bare soil and urban regions at VV and VH polarization of Sentinel-1A SAR satellite. It has potential to estimate the rate of depolarization in order to separate the bare soil scattering dominancy from the vegetation. The DPSVI had greater correlation than NDVI and other optical indices (Touzi et al. 2018). Therefore, the polarimetric study over the vegetation and soil using polarimetric SAR (PolSAR) is very important to exploit the theory of degree of polarization and coherency in the scattering mechanism derived from the decomposition and unitary transformation of n × n matrix (Vreugdenhil et al. 2018; Denize et al. 2019; Arias et al. 2020).

In this study, the two important characteristics of the SAR data (or radar scattering response) were exploited (i) the potential of the developed first order microwave scattering algorithm and (ii) formulation of dual polarimetric radar vegetation index from Sentinel - 1A (C - band) and ALOS-2 (L - band) SLC data. The backscattering of intermediate interactions from the vegetation-soil was incorporated in the zero order WCM and IEM for the development of first order microwave scattering algorithm. The dual polarimetric radar vegetation index (D_pRVI), polarimetric radar vegetation index (RVI) and radar vegetation index (RVI) were calculated at C - band (VV + VH) and L- band (HH + HV) using 2 × 2 polarimetric covariance scattering matrix and matrix decomposition techniques. The D_pRVI, PRVI and RVI were assessed as vegetation descriptors in the developed methodology for the appraisal of backscattering responses from the vegetation at VV/VH polarization.

7.2 STUDY AREA AND DATA CHARACTERISTICS

7.2.1 Study area

The proposed methodology was performed in the Varanasi city located in Indo-Gangetic planes of north India also named as Kashi with center coordinates of 25^0 19' 18.06" N and 82^0 59' 14.24" E. The geographical projection system of area is UTM (zone - 44, N) and WGS 84. This is considered as a holy city and one of the oldest human settlements in the world with population of almost 12 lakhs according to the Census 2011of India. Varanasi is situated between two rivers i.e. River Varuna and River Ganga enhancing the soil fertility for agriculture purpose. Figure 7.1 shows the RGB location map of the study region. The city experiences a humid subtropical with large variations between summer and winter temperature. The slope variation and elevation range are 0 % - 3 % and 0 - 98 meters, respectively. The agricultural regions of this city mainly covered wheat, barley and mustered in Rabi season and Rice in Kharif season.

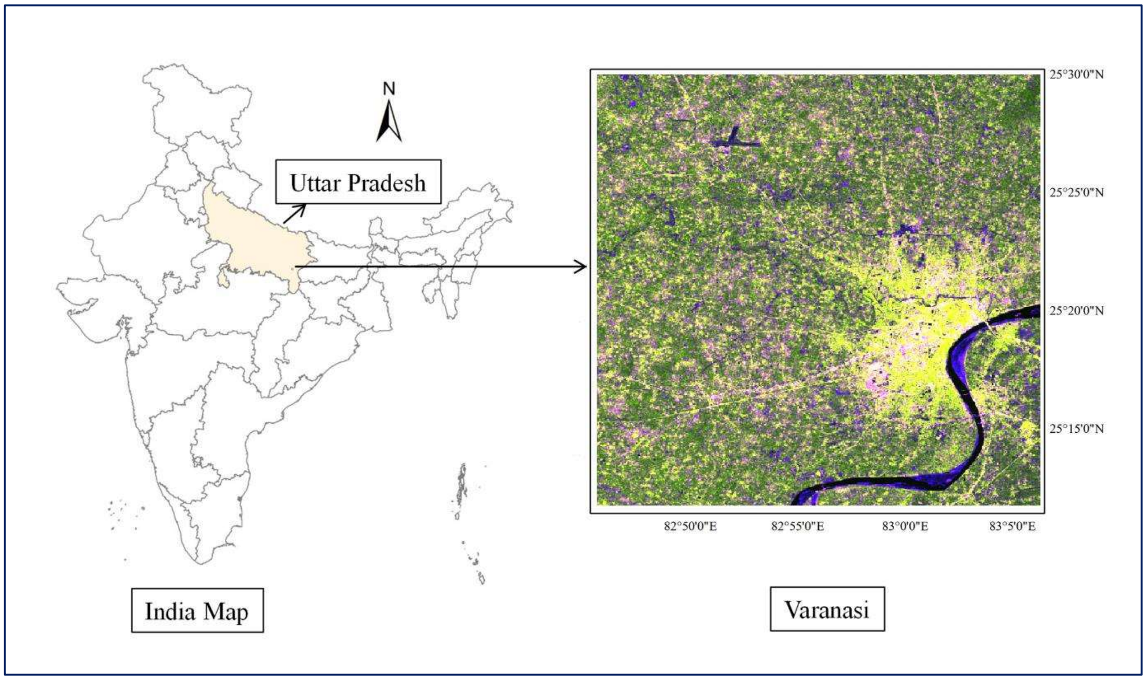


Figure 7.1 Sentinel -1A SAR RGB (R -VV, G – VH and B – VV/VH) image of the study location

7.2.2 In - situ measurements

The ground truth data was collected in the agricultural fields on March 12, 2019 during Sentinel -1A and ALOS -2 satellite passes over the study area. In each crop field, every point, representative of an area of 10 m × 10 m, was chosen for the sampling of soil moisture (m_v), roughness parameters and crop growth variable. The average of four measurements were computed as the final value of m_v at a depth of 0- 5.0 cm in each point and the values of the m_v was found in the range of 9.8 % to 28.3 %. Also, the average of four measurements were taken for the roughness parameters including surface rms height and correlation length. These values were computed from the soil surface profile meter, which was digitized from the roughness photographs. Whereas, the auto correlation function (Gaussian and exponential function) techniques were adopted for the computation of correlation length.

7.2.3 Satellite data

The Sentinel-1A, ALOS - 2 and Sentinel - 2 satellite images acquired on 12/03/2019 were used for the present study. The full detailed characteristics of following satellite data are shown in Table 7.1. The required image preprocessing of both SAR (Sentinel - 1A and ALOS - 2) and optical satellite (Sentinel - 2) images were completed using SNAP v.8.0 tool. The calibrations like radiometric, speckle filtering (Lee - sigma) and geometric correction were performed in both the SAR data. An enhanced Lee filter was carried out to reduce the speckle noise. The Sentinel -1A GRD data was used to computation of backscattering intensity which was converted into dB from the linear scale (Filipponi 2019). However, the SLC products were used to study PolSAR behavior of both Sentinel -1A and ALOS - 2. The Sentinel - 2 optical image was used for the computation of f_{veg} as a vegetation fraction parameter in the first order microwave scattering algorithm. The radiometric calibration and atmospheric correction were performed using ENVI - 5.1 (Bala et al., 2019). Finally, all images were co-registered for accurate interpretation of geo-location in the image.

Table 7.1 The detailed specifications of satellite data

Acquisition date	Satellite	Level	Products	Spectral regions
12/03/2019	ALOS - 2	L 1.5	SLC	L- band (1.2 GHz)
	Sentinel - 1A	L 1.0	SLC, GRD	C- band (5.405 GHz)
	Sentinel - 2	L 2.0	Multi -spectral	0.433 -2.190 µm

7.3 METHODOLOGY

The present study demonstrated the novel approach for the assessment of dual polarimetric radar vegetation index (C - and L - bands) as vegetation descriptors in the algorithm. The Figure

7.2 shows the illustration of proposed methodology for the simulation of modelled backscattered echoes from the vegetation and soil surface.

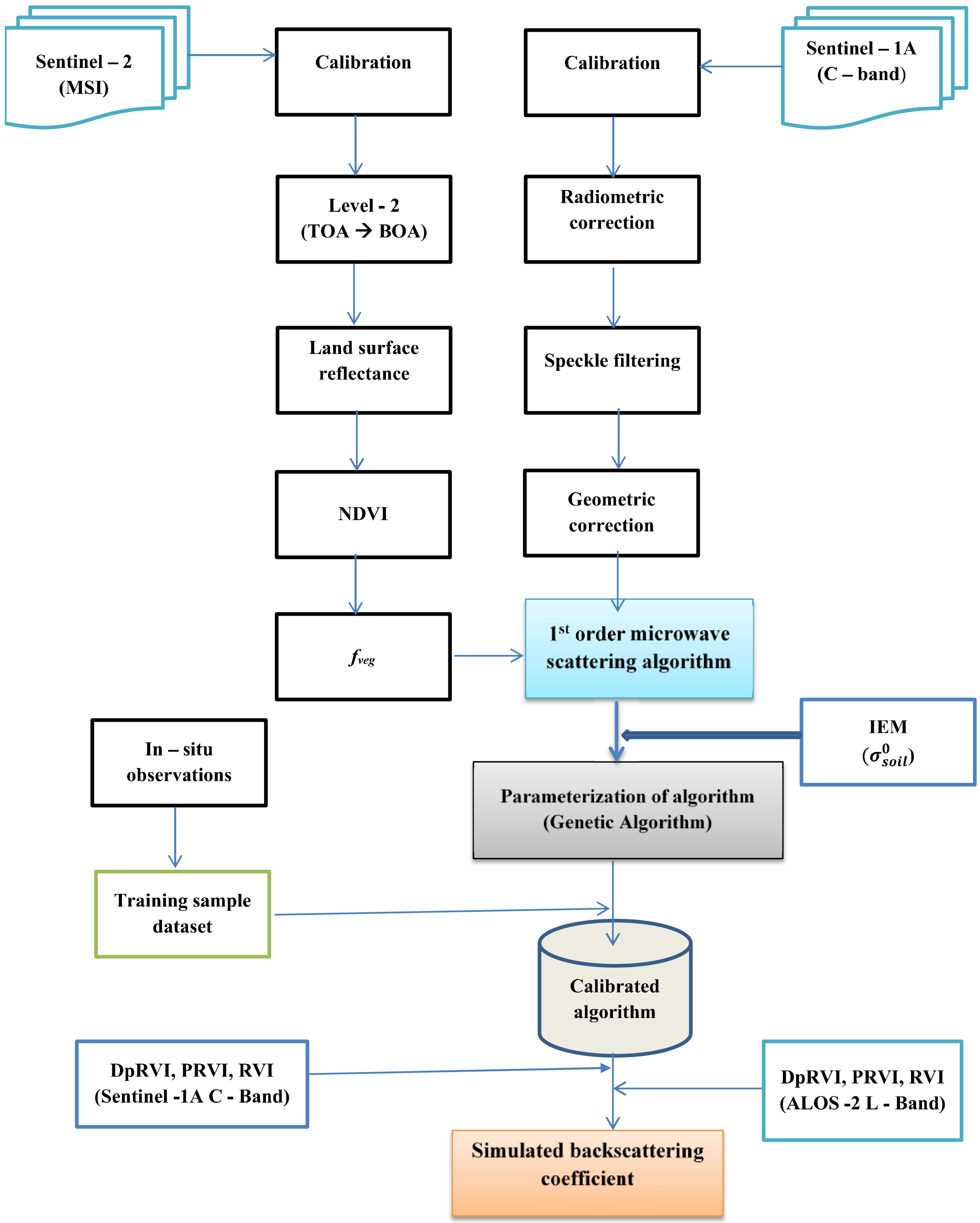


Figure 7.2 Illustration of general work flow for the appraisal of dual polarimetric radar vegetation index

7.3.1 First order microwave scattering algorithm

In the agricultural fields, the total backscatter coefficient (σ_T^0) from the vegetation and soil surfaces mainly expressed as the sum of contributions due to (i) volume scattering $\sigma_{veg}^0(V)$ from the vegetation canopy itself, (ii) surface scattering $\sigma_{soil}^0(\varepsilon_s, m_v, \theta)$ by the soil attenuated by the vegetation layer, and (iii) intermediate interactions $\sigma_{inter}^0(\varepsilon_s, m_v, \theta, V)$ between the vegetation canopy and the ground surface composed of volume scattering generated from the direct backscattering of the vegetation and the soil surface after the double attenuation, as follows :

$$\sigma_T^0 = \sigma_{veg}^0(V) + \sigma_{inter}^0(\varepsilon_r, m_v, \theta, V) + \tau^2 \sigma_{soil}^0(\varepsilon_r, m_v, h, \theta) \qquad (7.1)$$

where σ_{veg}^0 represents the backscattered radar signal from the vegetation canopy and σ_{soil}^0 is the backscattering response from bare soil surfaces. Whereas, τ^2 is defined as the two-way attenuation factor through vegetation-soil interfaces.

$$\sigma_{veg}^0 = AV^E cos\theta \left[1 - e^{-\left(\frac{2.B.V}{cos\theta}\right)}\right] \qquad (7.2)$$

$$\tau^2 = e^{-\left(\frac{2BV}{cos\theta}\right)} \qquad (7.3)$$

$$\sigma_{inter}^0(\varepsilon_s, m_v, \theta, V) = \gamma f_{veg}\, V\, \tau^2 \left|\frac{(\varepsilon_s - 1)(\sin^2\theta - \varepsilon_s(1 + \sin^2\theta))}{(\cos\theta + \sqrt{\varepsilon_s - \sin^2\theta})^2}\right|^2 \qquad (7.4)$$

Since, the depolarization of horizontal or vertical electric vector, during intermediate interactions of electromagnetic signals, is largely due to orientation of leaves, surface roughness and crop patterns. Hence, the precise study of $\sigma_{inter}^0(\varepsilon_s, m_v, \theta, V)$ is equally important to understand the SAR signal sensitivity and surface parameters which infer the backscattered echoes. The Equation (7.4) considered for the study of backscattering signal from the intermediate interaction is greatly dependent on soil dielectric constant (ε_s), vegeation fraction (f_{veg}) and vegetaion descriptor (V) and some unknown parameter.

$$f_{veg} = \frac{NDVI - NDVI^{bare}}{NDVI^{veg} - NDVI^{bare}} \tag{7.5}$$

In the soil Fresnel reflectivity, the ε_s is the relative soil dielectric constant (Du et al. 2000), which can be computed by using Equation (7.6)

$$\varepsilon_s = 114m_v^2 + 13.3m_v + 2.5 \tag{7.6}$$

The soil backscattering coefficients at VV polarization (σ_{soil}^0) can be expressed in term of soil surface (dielectric constant and roughness parameters) and SAR system parameters (wavevector ($k = \frac{2\pi}{\lambda}$), polarization (VV) and incidence angle (θ)). The Integral equation model (IEM) was incorporated in the first order microwave scattering algorithm for the computation of bare soil backscattering echoes. It also represents the rough surfaces scattering term approximated by the geometrical model (Kseneman et al. 2011). This can be defined as:

$$\begin{aligned} \sigma_{soil}^0 = {} & \frac{k}{2}|f_{VV}|^2 e^{-4k^2 h^2 \cos^2\theta} \sum_{n=1}^{\infty} \frac{(4k^2h^2\cos^2\theta)^n}{n!} W^{(n)}(2k\sin\theta, 0) \\ & + \frac{k}{2}\mathrm{Re}(f_{VV}^* F_{VV}) e^{-3k^2 h^2 \cos^2\theta} \sum_{n=1}^{\infty} \frac{(4k^2h^2\cos^2\theta)^n}{n!} W^{(n)}(2k\sin\theta, 0) \\ & + \frac{k}{8}|F_{VV}|^2 e^{-2k^2 h^2 \cos^2\theta} \sum_{n=1}^{\infty} \frac{(k^2h^2\cos^2\theta)^n}{n!} W^{(n)}(2k\sin\theta, 0) \end{aligned} \tag{7.7}$$

In the IEM expression, the $W^{(n)}$ is the Fourier transform of the unknown bare surface correlation function. Here, the gaussian function was used as the unknown correlation function. Whereas, the f_{VV} and F_{VV} represent the Kirchhoff coefficient and complementary field coefficient, respectively. Furthermore. these two coefficients are function of physical and geometrical parameters. The final expression of f_{VV} and F_{VV} can defined in Equations (7.8) and (7.9), respectively.

$$f_{VV} = \frac{2R_V}{\cos\theta} \tag{7.8}$$

$$F_{VV} = 2\frac{\sin^2\theta}{\cos\theta}\left[\left(1 - \frac{\varepsilon_r \cos^2\theta}{\mu_r\varepsilon_r - \sin^2\theta}\right)(1 - R_V)^2 + (1 - \frac{1}{\varepsilon_r})(1 + R_V)^2\right] \tag{7.9}$$

However, the parameter R_V in the above expression is known as the Fresnel coefficient at vertical polarization of incoming electromagnetic wave signal.

$$R_V = \frac{\varepsilon_r \cos\theta - \sqrt{\mu_r\varepsilon_r - \sin^2\theta}}{\varepsilon_r \cos\theta + \sqrt{\mu_r\varepsilon_r - \sin^2\theta}} \tag{7.10}$$

7.3.2 Radar vegetation descriptors

In this study, the three type of dual polarimetric radar vegetation index was assessed in the first order microwave scattering algorithm. The detailed computation of these radar vegetation descriptors has been discussed in the Chapter - 2 under the section of Materials and Methodology using Sentinel - 1A (VV +VH) and ALOS - 2 (HH + HV) SLC satellite data. The computational expression and results of radar index from both satellites are as follows:

7.3.2.1 Dual polarimetric radar vegetation index at L - band (1.2 GHz)

The computation of dual polarimetric radar index at L - band mainly depends on degree of polarization (m_L) and scattering energy span (sum of eigenvalues). The covariance scattering matrix (C_2^L) is primary factor to determine the m_L which decided the dominancy of scattering mechanism from the vegetation and soil surfaces at HH and HV polarization.

$$C_2^L = \begin{bmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{bmatrix} = \begin{bmatrix} < |s_{HH}|^2 > & < s_{HH}\, s_{HV}^* > \\ < s_{HV}\, s_{HH}^* > & < |s_{HV}|^2 > \end{bmatrix} \tag{7.11}$$

$$m_L = \sqrt{1 - \frac{4|C_2^L|}{(\mathrm{Tr}\,(C_2^L))^2}} \tag{7.12}$$

(1) Dual polarimetric radar vegetation index (D_pRVI)

$$D_pRVI = 1 - m_L\beta \qquad 0 \le D_pRVI \ge 1 \tag{7.13}$$

$$\beta = \frac{\lambda_1}{\lambda_1 + \lambda_2}$$

(2) Polarimetric radar vegetation index (PRVI)

$$RVI = (1 - m_L)\, \sigma^0_{HV} \tag{7.14}$$

(3) Radar vegetation index (RVI)

$$RVI = \frac{4\,\sigma^0_{HV}}{\sigma^0_{HH} + \sigma^0_{HV}} \tag{7.15}$$

7.3.2.2 Dual polarimetric radar vegetation index at C -band (5.405 GHz)

The computation of dual polarimetric radar vegetation index for C- band is similar to the L - band, however, the covariance scattering matrix (C_2^C) is at VV + VH polarization. Therfore, the all the computed radar index infers the scattering energy at the frequency 5.405 GHz.

$$C_2^C = \begin{bmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{bmatrix} = \begin{bmatrix} < |s_{VV}|^2 > & < s_{VV}\, s^*_{VH} > \\ < s_{VH}\, s^*_{VV} > & < |s_{VH}|^2 > \end{bmatrix} \tag{7.16}$$

$$m_C = \sqrt{1 - \frac{4|C_2^C|}{(\mathrm{Tr}\,(C_2^C))^2}} \tag{7.17}$$

(1) Dual polarimetric radar vegetation index (D_pRVI)

$$D_pRVI = 1 - m_C\beta \qquad 0 \le D_pRVI \ge 1 \tag{7.18}$$

$$\beta = \frac{\lambda_1}{\lambda_1 + \lambda_2}$$

(2) Polarimetric radar vegetation index (PRVI)

$$PRVI = (1 - m_C)\, \sigma^0_{VH} \tag{7.19}$$

(3) Radar vegetation index (RVI)

$$RVI = \frac{4\,\sigma^0_{VH}}{\sigma^0_{VV} + \sigma^0_{VH}} \tag{7.20}$$

7.3.3 Parameterization of first order microwave scattering algorithm

The Equation (7.1) contains some unknown model parameters (A, E, B and γ). The Genetic optimization algorithm was considered for the parametrization of algorithm and computation of unknown model parameters.

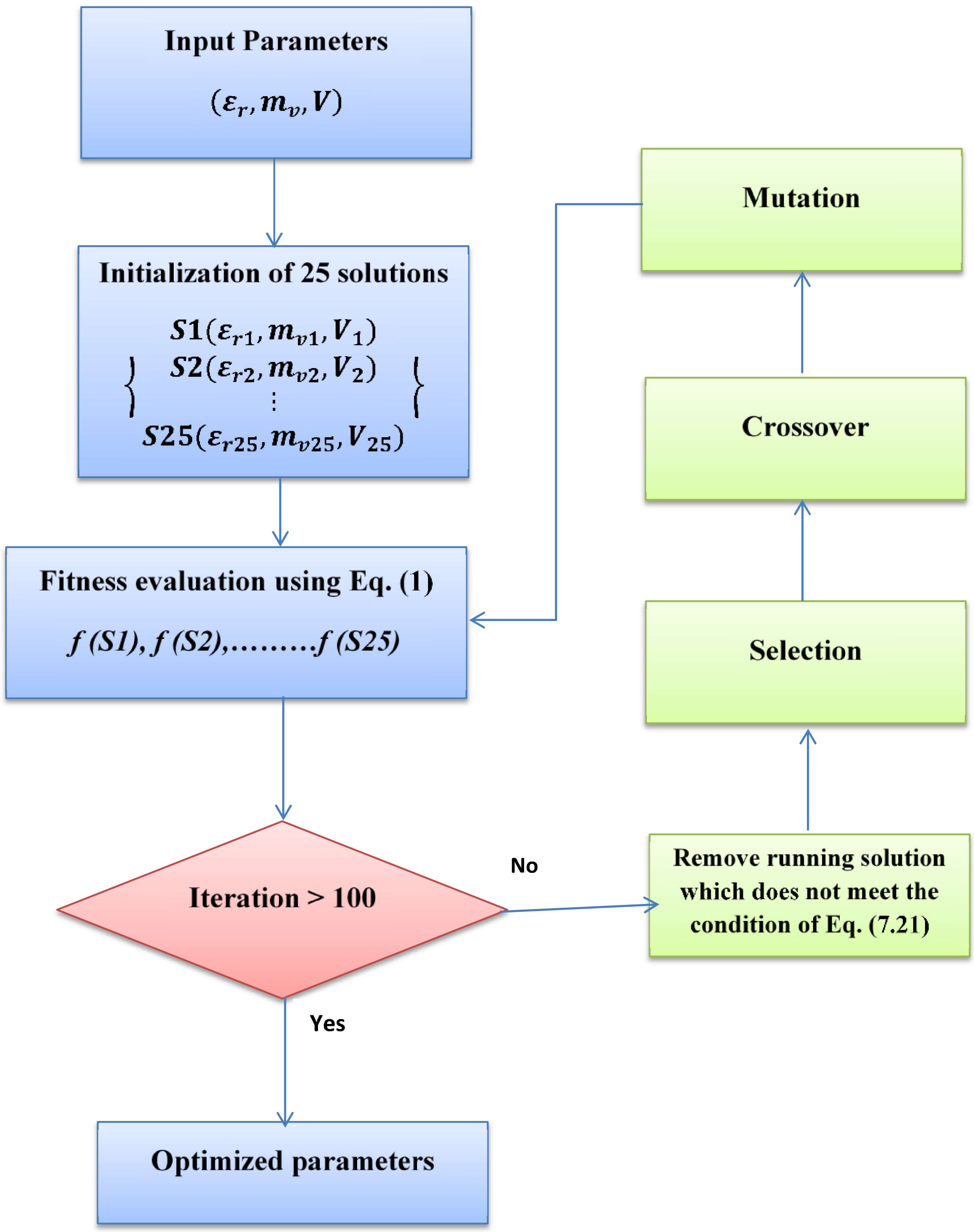


Figure 7.3 Parametrization work flow of Genetic algorithm for model optimization

The Figure (7.3) shows the general frame work of Genetic optimization algorithm for the computation of unknown model parameters in first order microwave scattering algorithm. The Genetic algorithm has low risk of reaching a local minimum and its convenience to integrate with the constraints. The initialization of Genetic optimization algorithm dependent on the number of chromosome (25 chromosomes) generation.

$$\text{cost function (f)} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\sigma^0_{VV} - \sigma^0_{mod}(\varepsilon_s, m_v, \theta, V))^2} \tag{7.21}$$

The optimum solution of model parameters was adaptively selected for three operation (selection, crossover and mutation) to minimized the cost function. The optimized parameters are shown in the Table 7.2 for different radar vegetation index at C - and L - bands.

Table 7.2 Optimized model parameters value at C - and L - band frequencies

Index	**C- band**				**L- band**			
	A	**E**	**B**	γ	**A**	**E**	**B**	γ
DpRVI	-1.567	0.125	-0.027	3.121	-1.944	0.176	-0.018	1.974
PRVI	-1.450	0.342	-0.012	4.672	-1.675	0.443	-0.034	2.581
RVI	-1.982	0.575	-0.056	2.784	-2.831	0.548	-0.068	1.563

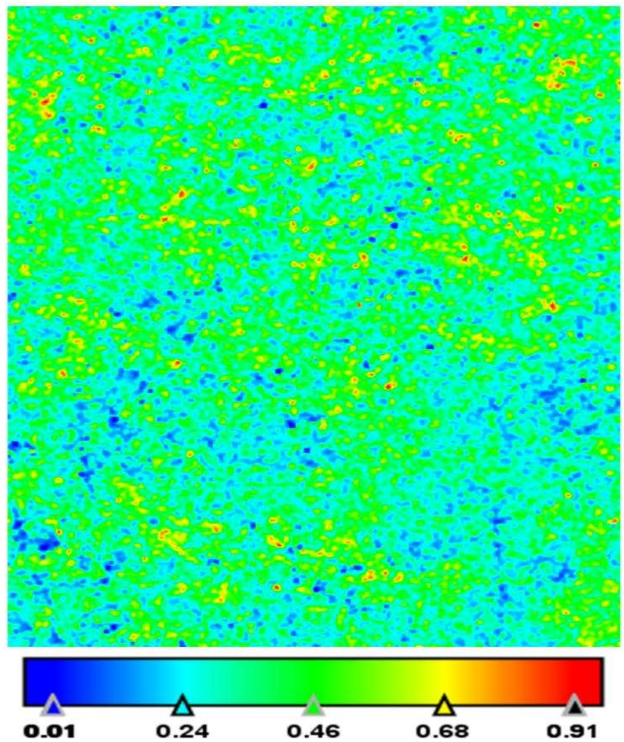
7.4 RESULTS AND DISCUSSION

7.4.1 Computation of D_pRVI, PRVI and RVI at L - band (HH + HV)

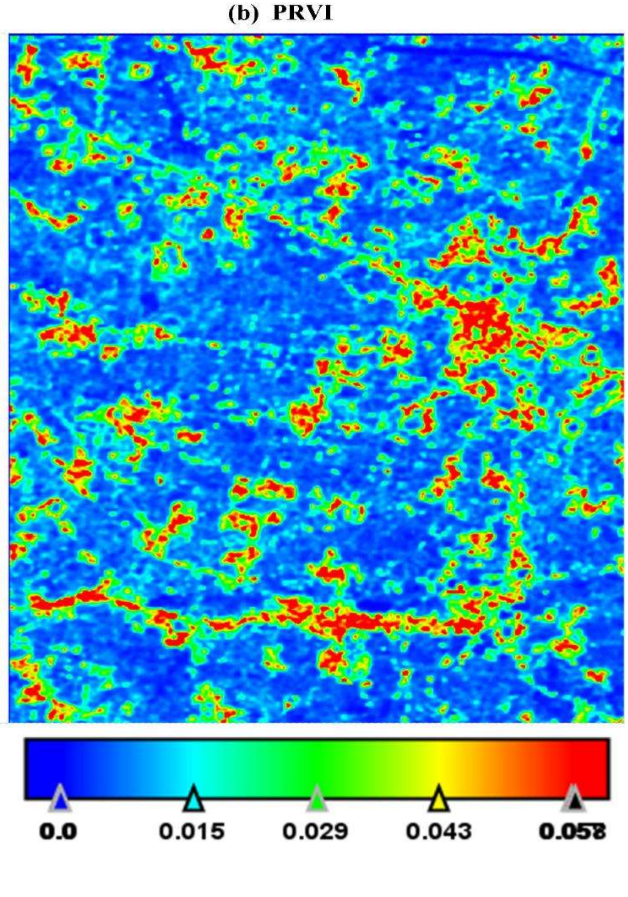
The ALOS - 2 SLC (L 1.5) satellite data was used for the computation of D_pRVI, PRVI and RVI at L- band. All the field sampling was performed on the selected vegetative land cover for the wheat crop. Figure (7.4) shows the simulated map for the (a) D_pRVI, (b)PRVI and (c)RVI over the wheat crop fields using mathematical expression that has been discussed in the above methodology section. The D_pRVI is the function of degree of polarization (m) and dominancy of scattering energy span (λ_1 / λ_1+ λ_2) which was computed from second order spatial average of covariance scattering vector matrix (C_2^L). Actually, the D_pRVI is bounded between 0 (bare soil) to 1 (at very dense canopy) and its value increases with the increase of vegetation canopy (wheat crop). The PRVI is unbounded parameter and mainly influences by the unpolarized wave vector (1 - m) values. Moreover, '*m*' is defined as the ratio of the (average) intensity of the polarized portion of the electromagnetic wave to that of the (average) total intensity of the wave. The value of $m = 1$ corresponds to completely polarized electromagnetic wave, whereas its value $m = 0$ represents a completely unpolarized electromagnetic wave. Due to the higher penetrating power of L- band, the values of m may be more sensitive with the vegetation canopy and underlying soil surfaces as compared to C - band.

For the early stage of crop growth, the energy span λ_1 / λ_1+ λ_2 is less than λ_2 / λ_1+ λ_2 due to dominant contribution of underlying soil parameters. Therefore, at the dense canopy stage of the crop, the value of m is found relatively lower than leaf development (early stage) of the wheat crop. Hence, the value of D_pRVI increases with the increase in the crop growth variables (least dominancy of high order scattering). Resulting D_pRVI values depend on the type of crops (canopy density), multiple scattering and farmer practices (row column plantation).

(a) D_pRVI



(b) PRVI



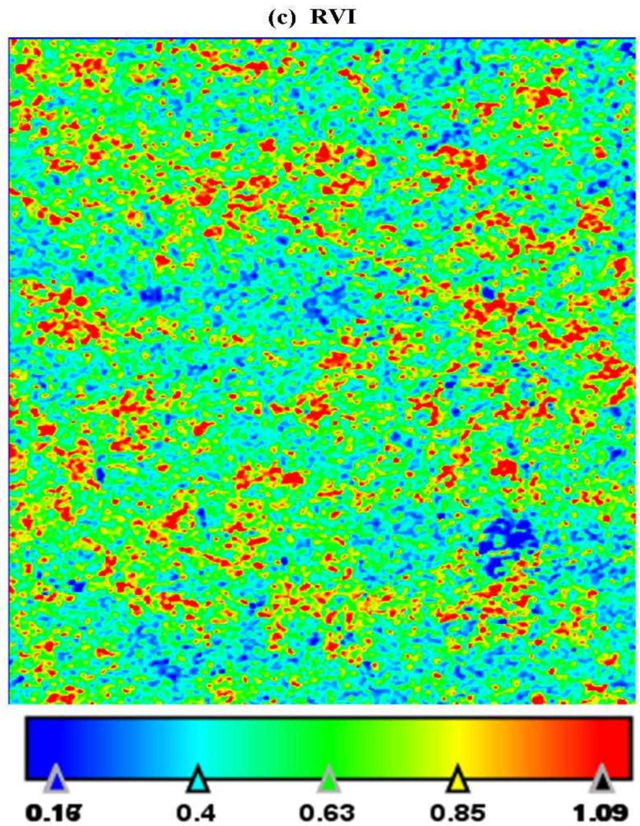
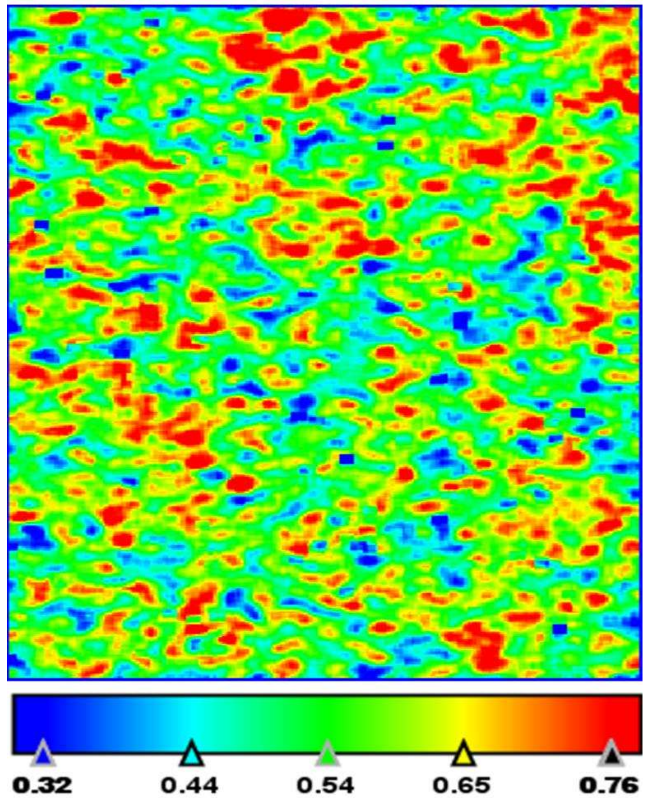


Figure 7.4 Computed map of (a) D_pRVI, (b) PRVI and (c) RVI from ALOS-2 (L- band) satellite data

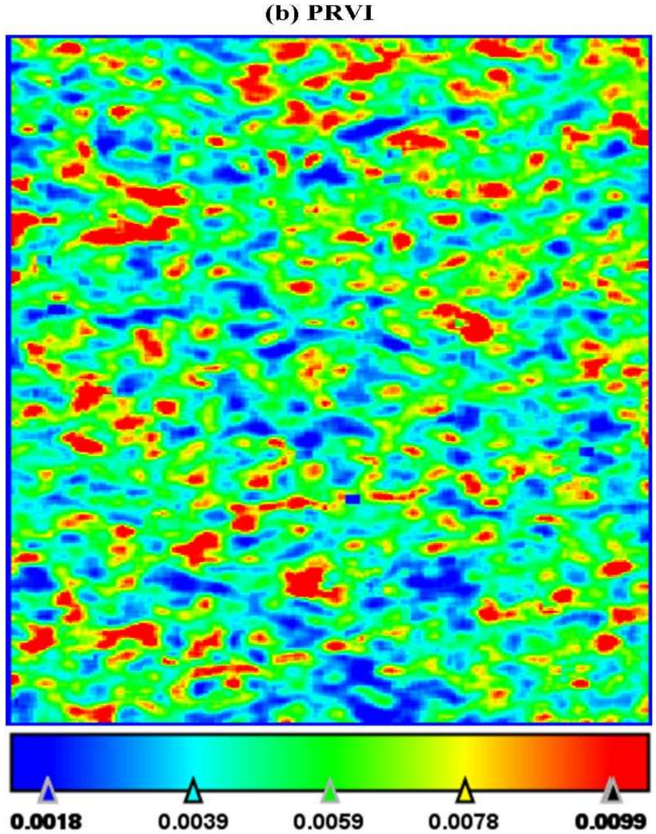
7.4.2 Computation of D_pRVI, PRVI and RVI at C - band (VV + VH)

The Sentinel -1A SLC data was selected for the computation of D_pRVI, PRVI and RVI at VV and VH polarization scattering vectors. The Figure (7.5) shows the simulated map of (a) D_pRVI (b) PRVI and (c) RVI, respectively. Their computational techniques were followed at VV and VH polarizations. Similarly, the D_pRVI values at C - band were found in the range of 0 to 1 (bounded) as per crop growth conditions. The PRVI and RVI also followed the crop phenological stages and characterised the development of wheat crop canopy. The decomposition of matrix (C_2^C) at VV and VH polarizations caused the variation of these indexes values as compared to HH + HV polarization. Because, the system (polarization and frequency) parameters and wheat crop canopy development and orientation of leaves are the major factors for depolarization of the wave signal.

(a) DpRVI



(b) PRVI



(c) RVI

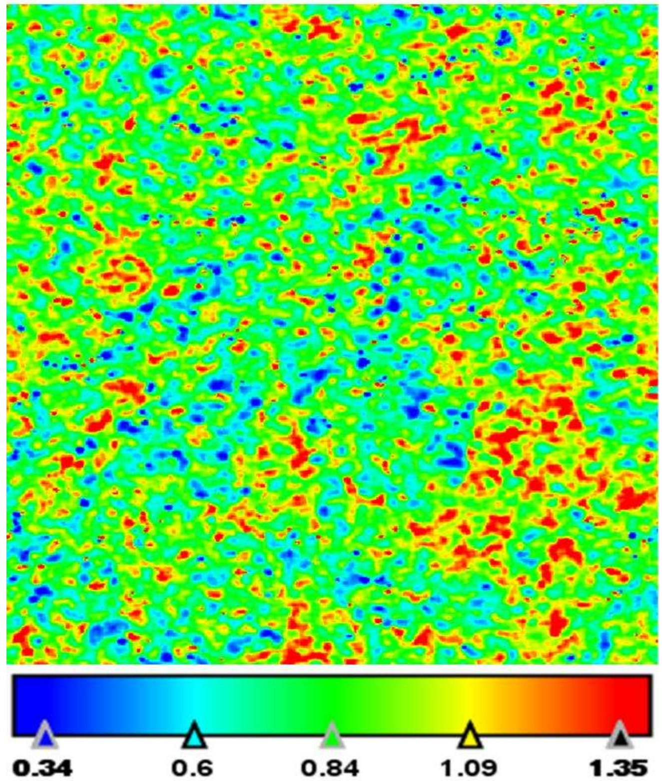
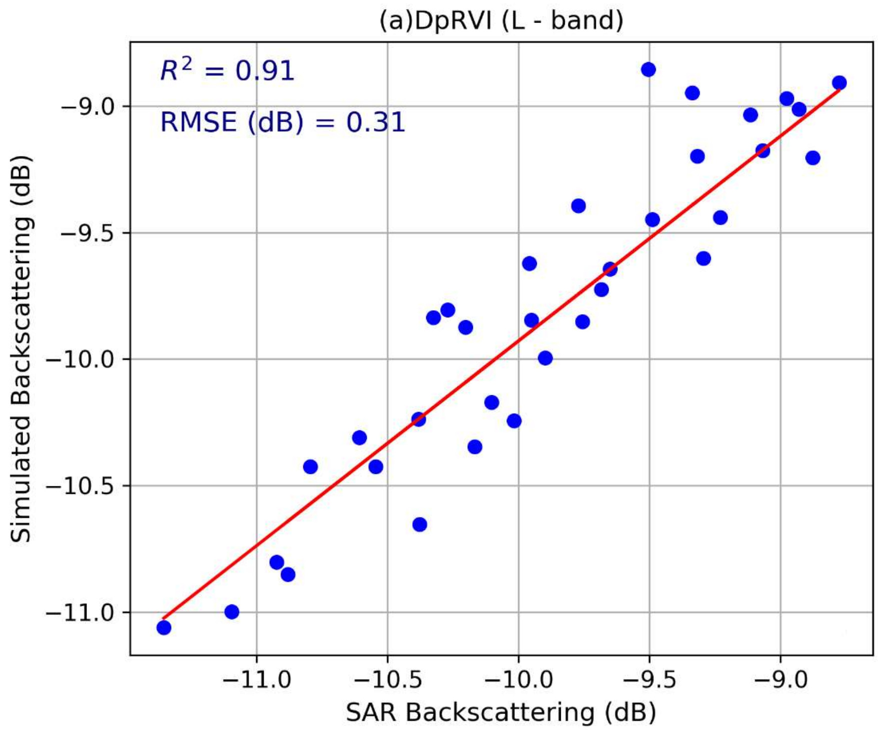


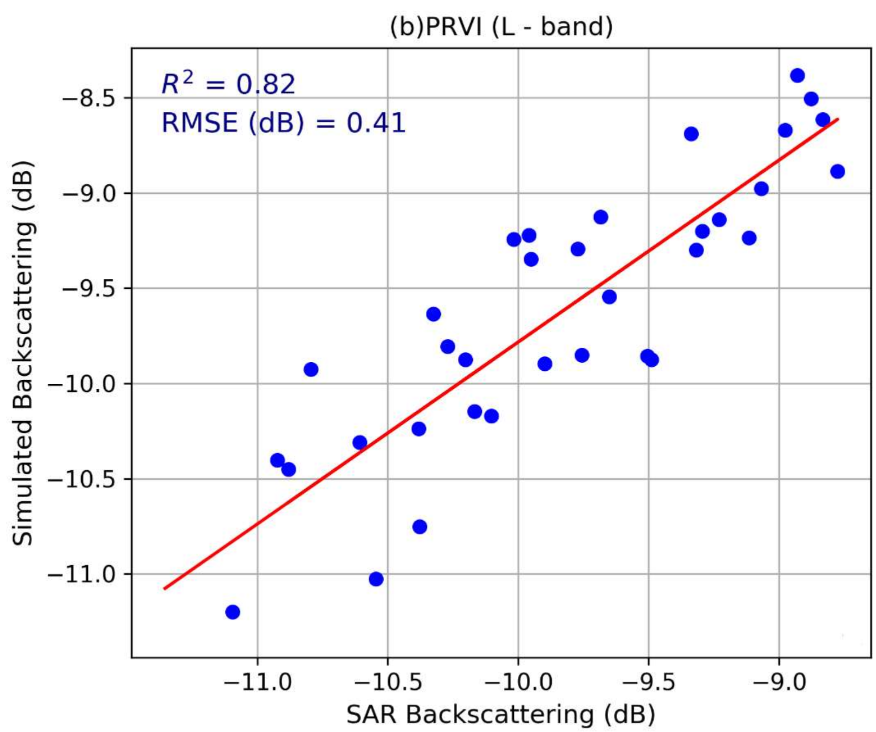
Figure 7.5 Computed map of (a) D_pRVI, (b) PRVI and (c) RVI from Sentinel -1A (C- band) satellite data

7.4.3 Appraisal of dual polarimetric radar vegetation index at L - band (HH + HV polarization) in the first order microwave scattering algorithm

The potential of dual polarimetric radar vegetation indexes were assessed in the first order microwave scattering algorithm after the parametrization (i.e. computation of optimized model parameters). Figure 7.6 shows the performance of developed model and (a) D_pRVI, (b) PRVI and (c) RVI as vegetation descriptors for the simulation of backscattering coefficient (forward modelling). The D_pRVI showed the higher $R^2 = 0.91$ and lower RMSE = 0.31 (dB) as compared to the PRVI and RVI at L- band. Since, the D_pRVI is more sensitive with crop growth due to fairly separation of unpolarized scattering (1 - *m*) wave from the crop canopy and underlying soil geometry. The β factor has capability to decide the dominant scattering weighted from the canopy and soil surface. Therefore, the both *m* and β parameters enrich the potential of D_pRVI

vegetation descriptor in the developed microwave algorithm as compared to PRVI and RVI at L - band (1.2 GHz).





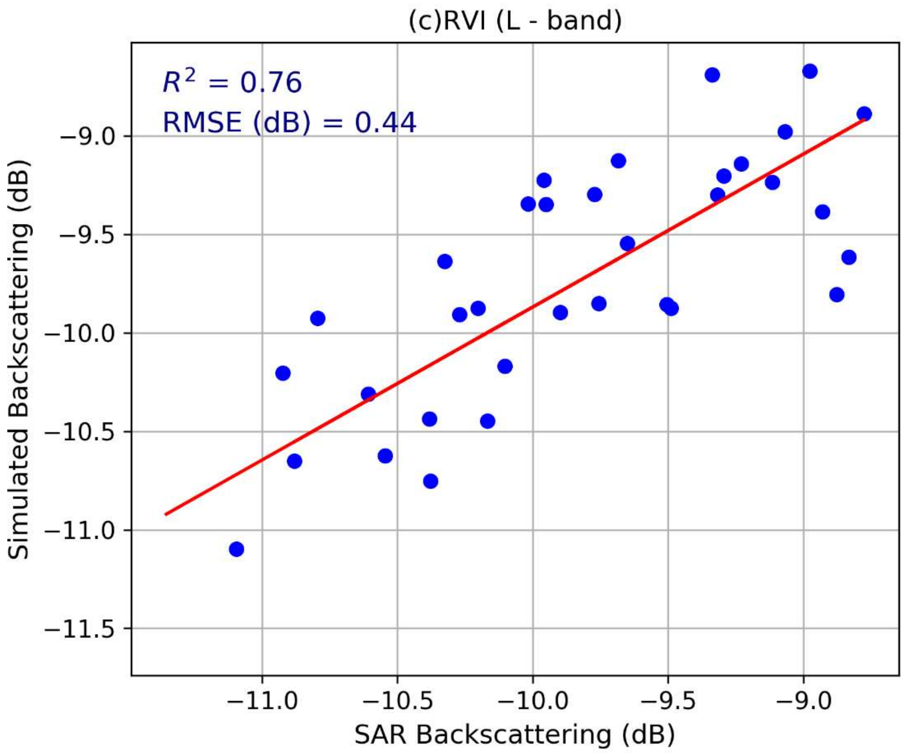
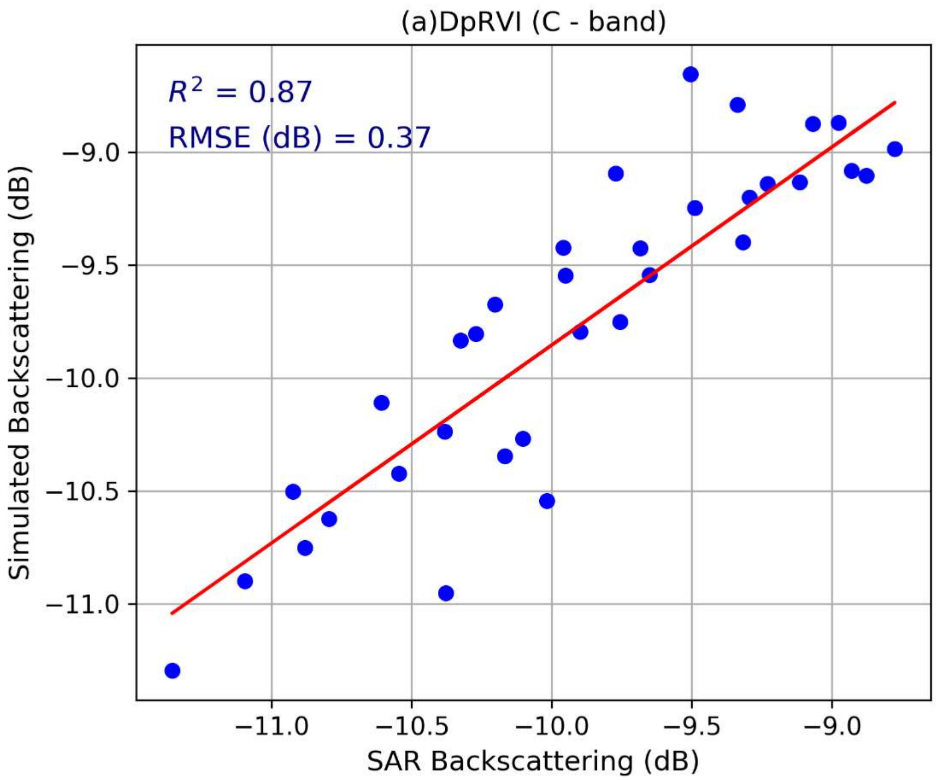
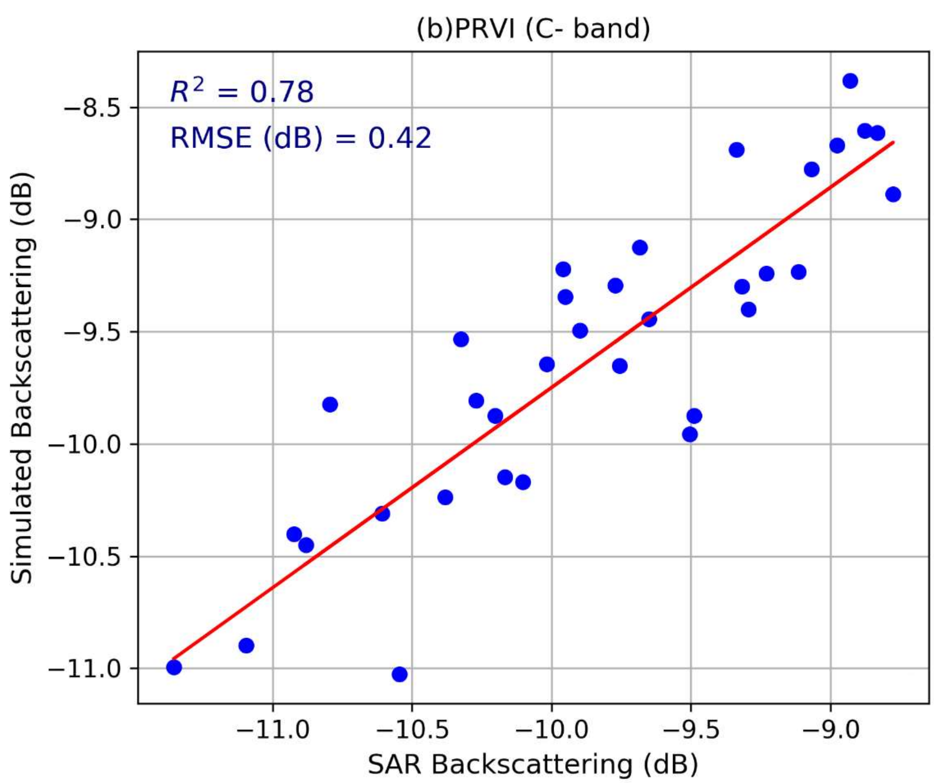


Figure 7.6 Comparative analysis between simulated and Sentinel -1A backscattering coefficient using vegetation descriptors (a) D_pRVI, (b) PRVI and (c) RVI at HH + HV polarization

7.4.4 Appraisal of dual polarimetric radar vegetation index at C- band (VV + VH polarization) in the first order microwave scattering algorithm

The computed radar indexes from the covariance matrix were tested in the developed first order microwave scattering algorithm for wheat crop at VV polarization. The D_pRVI, PRVI and RVI were computed from VV and VH dual polarization second order covariance matrix. Similarly, the D_pRVI indicated higher accuracy (R^2 = 0.87 and RMSE = 0.37 dB) of simulated backscattering coefficient from the developed vegetation scattering algorithm than that of PRVI and RVI (Figure 7.7). Since, the scattering energy covariance matrix was found correlated only with the vertically polarized transmitted and depolarized horizontal wave which infers the different mechanism of D_pRVI at C - band (5.405 GHz) than the horizontally polarized transmitted wave at L-band (1.2 GHz).


(a)DpRVI (C - band)
R^2 = 0.87
RMSE (dB) = 0.37
Simulated Backscattering (dB)
SAR Backscattering (dB)
−9.0
−9.5
−10.0
−10.5
−11.0
−11.0
−10.5
−10.0
−9.5
−9.0


(b)PRVI (C- band)
R^2 = 0.78
RMSE (dB) = 0.42
Simulated Backscattering (dB)
SAR Backscattering (dB)
−8.5
−9.0
−9.5
−10.0
−10.5
−11.0
−11.0
−10.5
−10.0
−9.5
−9.0

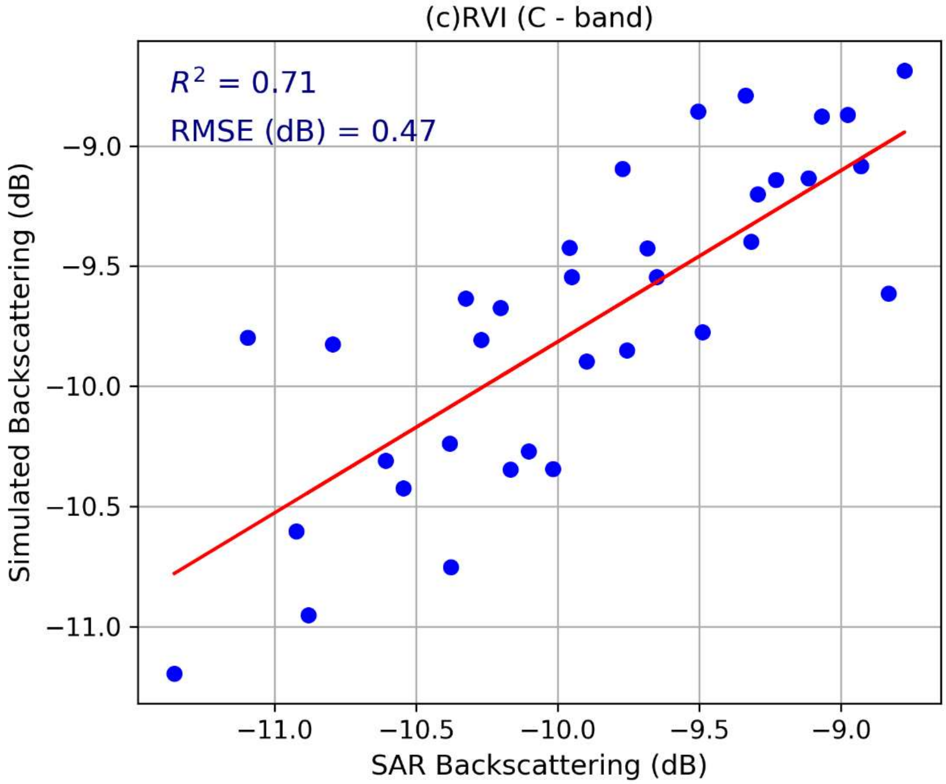


Figure 7.7 Comparative analysis between simulated and Sentinel -1A backscattering coefficient using vegetation descriptors (a) D_pRVI, (b) PRVI and (c) RVI at VV + VH polarization

7.5 CONCLUSION

In this study, the potential of three radar vegetation index (i.e. D_pRVI, PRVI and RVI) were evaluated in the developed of the first order microwave scattering algorithm. The intermediate interaction of incoming electromagnetic wave energy (backscattered echoes) from the soil and vegetation layers were incorporated for the development of the first order scattering algorithm. However, the bare soil backscattering intensities were simulated from the physical based IEM at VV using Sentinel - 1A GRD data. For the calculation of radar indexes, the ALOS - 2 (L - band) and Sentinel -1A (C - band) SLC data was used for computation of D_pRVI, PRVI and RVI at dual polarization HH + HV and VV + VH, respectively.

Among the results obtained from the three radar vegetation descriptor parameters in the developed algorithm, the D_pRVI showed the greater sensitivity at both C- and L- band frequencies than that of PRVI and RVI for the wheat crop. However, the D_pRVI computed from HH + HV (L - band) indicated additional potential than that of D_pRVI at VV + VH (C - band). Therefore, the DpRVI (at L - band) effectively incorporates the backscattered wave information to describe the growth changes that are crucial for time-series vegetation monitoring from the space platform at all weather conditions. Hence, the D_pRVI could be used as an operational radar vegetation growth index for the various SAR orbiting sensors (RADARSAT - 2 and TerraSAR - X) or near future SAR mission (like NISAR and RISAT - 2).