Generalized Radar Vegetation Index: GRVI Standalone Toolbox v1.0

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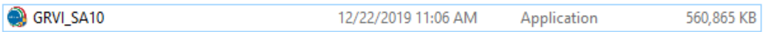
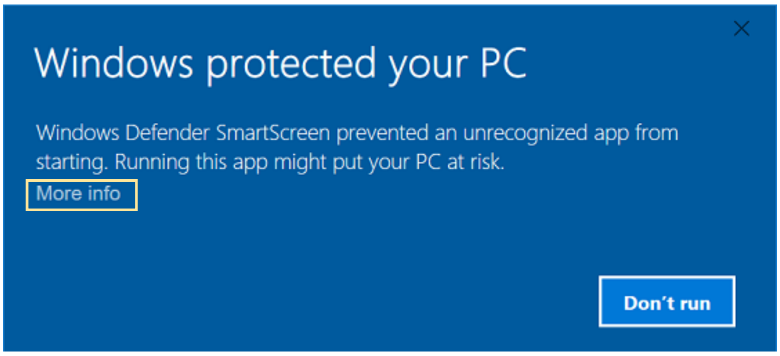
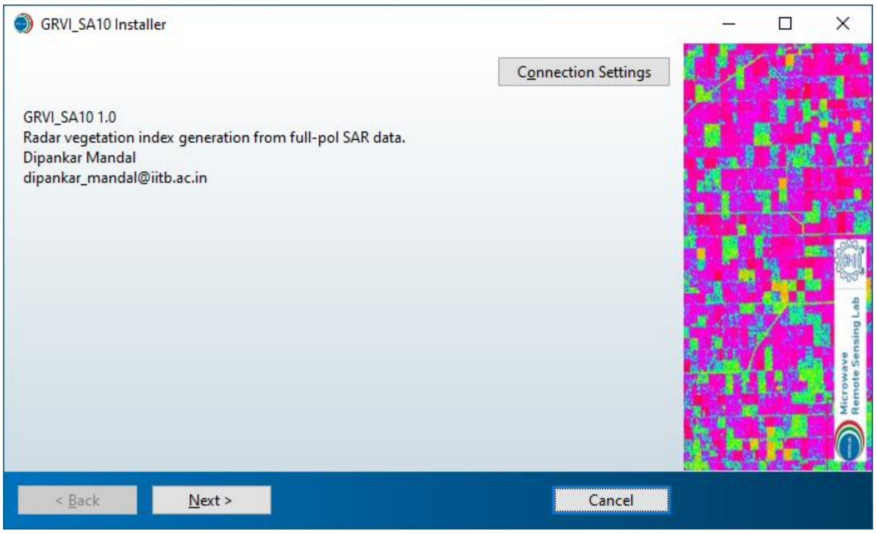
1. Download GRVI_SA10.exe file from:



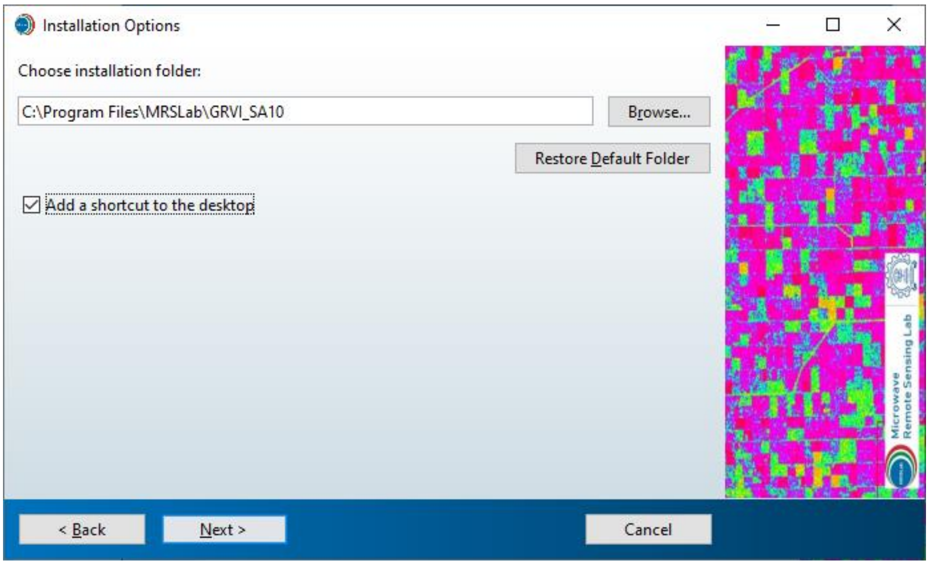
2. Installation:
   The executable file includes the MATLAB runtime setup as well. Therefore, we can directly install the GRVI_SA10.exe in windows by double clicking.
   You may get the windows defender popup message box. Click on 'More info' and then 'Run anyway' button.



It appears the installer dialog box. Now, you have to run 'Next' button, and proceed further.



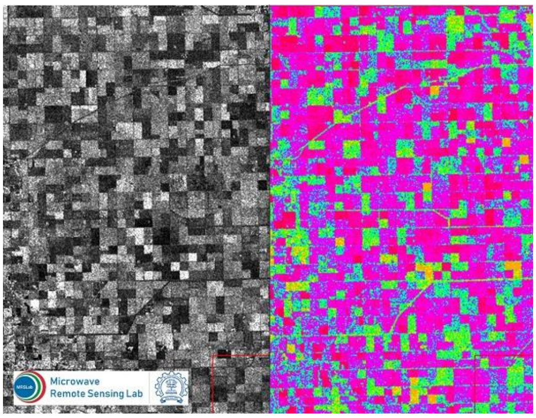
Select installation directory and check in the 'Add a shortcut to desktop'. Hit the 'Next' button.

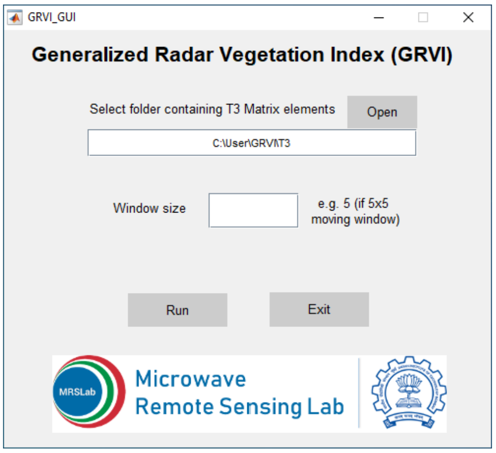


Now follow the next button and finish the installation. In this step, MATLAB runtime is being installed, which may takes couple of minutes.

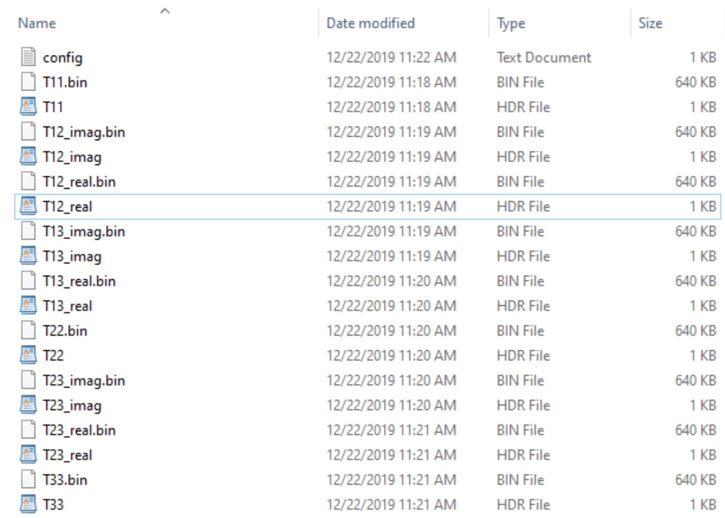
3. Accessing the GRVI_SA10 toolbox:
   On the desktop you can find the icon:

   Just double click on the shortcut icon and it launches the tool. First a splash window pops up and later the tool is visible:



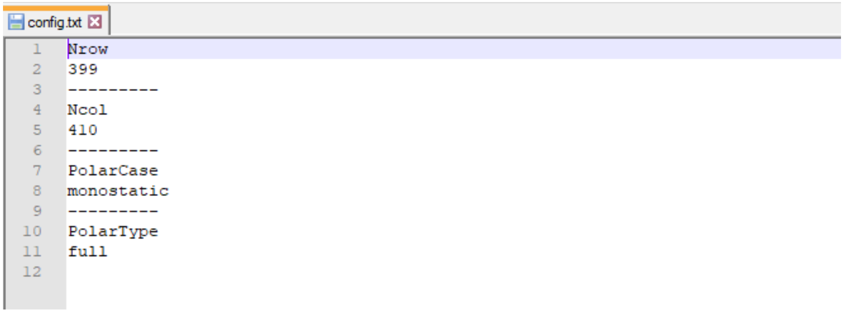


4. Input-folder structure for the tool:
   For generating the GRVI, you need a quad-pol SAR data. The quad-pol data (e.g. RADARSAT-2, ALOS-2, UAVSAR etc.) need to be preprocessed to generate a 3x3-coherency matrix (T3). This preprocessing steps can be achieved using PolSARPro (http://step.esa.int/main/toolboxes/polsarpro-v6-0-biomass-edition-toolbox/) or SNAP (http://step.esa.int/main/download/snap-download/). The final T3 matrix should be saved in PolSARPro format (binary files with header and a config file). The T3 folder structure should be in following form:



Name	Date modified	Type	Size
config	12/22/2019 11:22 AM	Text Document	1 KB
T11.bin	12/22/2019 11:18 AM	BIN File	640 KB
T11	12/22/2019 11:18 AM	HDR File	1 KB
T12_imag.bin	12/22/2019 11:19 AM	BIN File	640 KB
T12_imag	12/22/2019 11:19 AM	HDR File	1 KB
T12_real.bin	12/22/2019 11:19 AM	BIN File	640 KB
T12_real	12/22/2019 11:19 AM	HDR File	1 KB
T13_imag.bin	12/22/2019 11:19 AM	BIN File	640 KB
T13_imag	12/22/2019 11:19 AM	HDR File	1 KB
T13_real.bin	12/22/2019 11:20 AM	BIN File	640 KB
T13_real	12/22/2019 11:20 AM	HDR File	1 KB
T22.bin	12/22/2019 11:20 AM	BIN File	640 KB
T22	12/22/2019 11:20 AM	HDR File	1 KB
T23_imag.bin	12/22/2019 11:20 AM	BIN File	640 KB
T23_imag	12/22/2019 11:20 AM	HDR File	1 KB
T23_real.bin	12/22/2019 11:21 AM	BIN File	640 KB
T23_real	12/22/2019 11:21 AM	HDR File	1 KB
T33.bin	12/22/2019 11:21 AM	BIN File	640 KB
T33	12/22/2019 11:21 AM	HDR File	1 KB

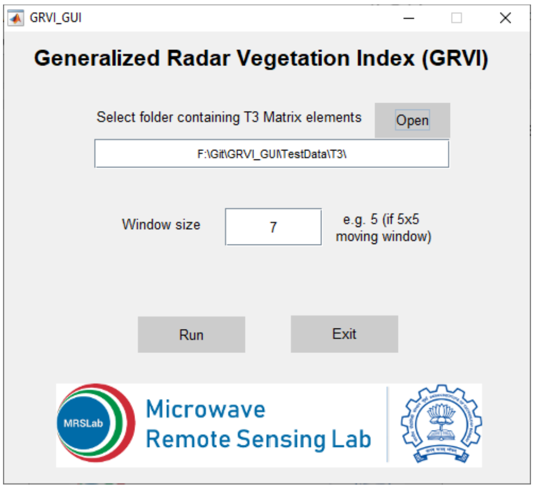
The config.txt file includes the row and column number information and structures as:

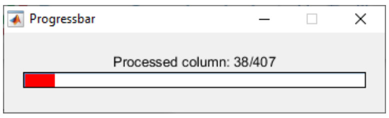



```
Nrow
399
---------
Ncol
410
---------
PolarCase
monostatic
---------
PolarType
full
```

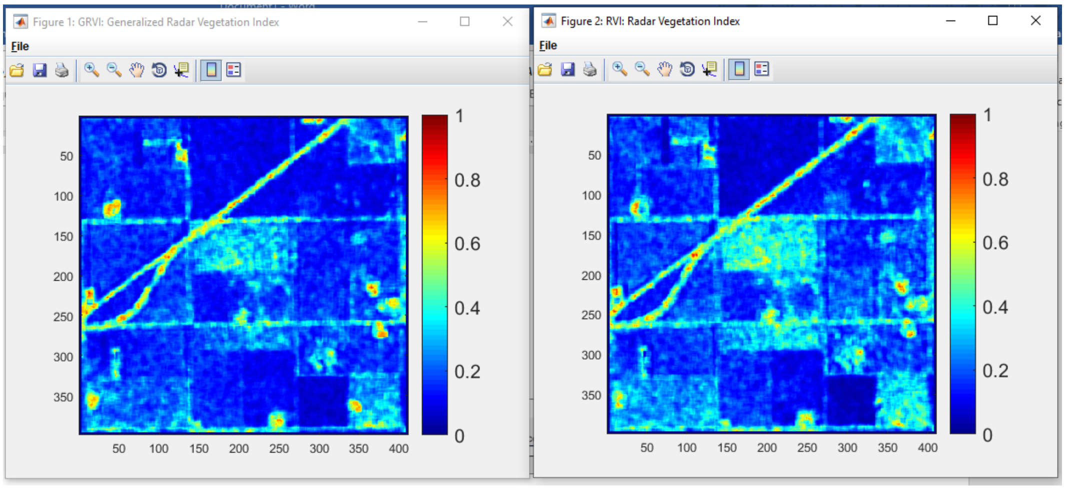
In general, PolSARPro generates this kind of structures, so you do not have to worry about it. If you are processing the data with SNAP, then just create a dummy config.txt file in the same order (the elements of config.txt file is case sensitive).

5. Running the tool:
   The user interface seeks the T3 folder path and processing window size as input. After these two entries, hit the 'Run' button and the processing starts with a progressbar (shows the processed columns instances).





After the end of the processing the progressbar hides automatically and two 'Figure' window pops up. These two window contains GRVI and RVI outputs generated from the given dataset. The GRVI and RVI binary files are generated in the background within the same path (of the dataset).



In addition, these Figures are also stored as .png and .fig format in the same path.

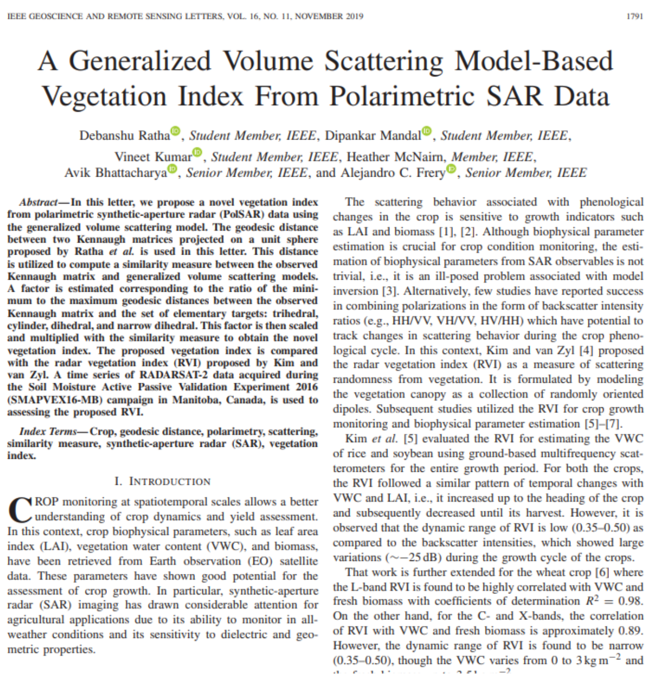
6. Additional Tips:

Window size: Users should use odd windows sizes starting from (3x3, 5x5, 7x7, 9x9,…).
We suggest do not use 1x1 window.

Image size: There is no restriction in image size (row and columns). However, for larger row and columns the process may take several minutes.

Opening the GRVI.bin files: To open the GRVI.bin file you can use ENVI or MATLAB or other tools. It asks for header files (.hdr), which is exactly same as the T3 elements. It can be manually copied from T11.hdr and then you have to create a GRVI.hdr using notepad.

7. Theory of GRVI:
Users are encouraged to read the following research articles for theory and formulation of GRVI.



IEEE GEOSCIENCE AND REMOTE SENSING LETTERS, VOL. 16, NO. 11, NOVEMBER 2019 1791

A Generalized Volume Scattering Model-Based Vegetation Index From Polarimetric SAR Data

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***Abstract*—In this letter, we propose a novel vegetation index from polarimetric synthetic-aperture radar (PolSAR) data using the generalized volume scattering model. The geodesic distance between two Kennaugh matrices projected on a unit sphere proposed by Ratha *et al.* is used in this letter. This distance is utilized to compute a similarity measure between the observed Kennaugh matrix and generalized volume scattering models. A factor is estimated corresponding to the ratio of the minimum to the maximum geodesic distances between the observed Kennaugh matrix and the set of elementary targets: trihedral, cylinder, dihedral, and narrow dihedral. This factor is then scaled and multiplied with the similarity measure to obtain the novel vegetation index. The proposed vegetation index is compared with the radar vegetation index (RVI) proposed by Kim and van Zyl. A time series of RADARSAT-2 data acquired during the Soil Moisture Active Passive Validation Experiment 2016 (SMAPVEX16-MB) campaign in Manitoba, Canada, is used to assessing the proposed RVI.**

***Index Terms*—Crop, geodesic distance, polarimetry, scattering, similarity measure, synthetic-aperture radar (SAR), vegetation index.**

I. INTRODUCTION

CROP monitoring at spatiotemporal scales allows a better understanding of crop dynamics and yield assessment. In this context, crop biophysical parameters, such as leaf area index (LAI), vegetation water content (VWC), and biomass, have been retrieved from Earth observation (EO) satellite data. These parameters have shown good potential for the assessment of crop growth. In particular, synthetic-aperture radar (SAR) imaging has drawn considerable attention for agricultural applications due to its ability to monitor in all-weather conditions and its sensitivity to dielectric and geometric properties.

The scattering behavior associated with phenological changes in the crop is sensitive to growth indicators such as LAI and biomass [1], [2]. Although biophysical parameter estimation is crucial for crop condition monitoring, the estimation of biophysical parameters from SAR observables is not trivial, i.e., it is an ill-posed problem associated with model inversion [3]. Alternatively, few studies have reported success in combining polarizations in the form of backscatter intensity ratios (e.g., HH/VV, VH/VV, HV/HH) which have potential to track changes in scattering behavior during the crop phenological cycle. In this context, Kim and van Zyl [4] proposed the radar vegetation index (RVI) as a measure of scattering randomness from vegetation. It is formulated by modeling the vegetation canopy as a collection of randomly oriented dipoles. Subsequent studies utilized the RVI for crop growth monitoring and biophysical parameter estimation [5]–[7].

Kim *et al.* [5] evaluated the RVI for estimating the VWC of rice and soybean using ground-based multifrequency scatterometers for the entire growth period. For both the crops, the RVI followed a similar pattern of temporal changes with VWC and LAI, i.e., it increased up to the heading of the crop and subsequently decreased until its harvest. However, it is observed that the dynamic range of RVI is low (0.35–0.50) as compared to the backscatter intensities, which showed large variations (∼−25 dB) during the growth cycle of the crops.

That work is further extended for the wheat crop [6] where the L-band RVI is found to be highly correlated with VWC and fresh biomass with coefficients of determination $R^2 = 0.98$. On the other hand, for the C- and X-bands, the correlation of RVI with VWC and fresh biomass is approximately 0.89. However, the dynamic range of RVI is found to be narrow (0.35–0.50), though the VWC varies from 0 to 3 $kg\,m^{-2}$ and

Ratha, D., Mandal, D., Kumar, V., McNairn, H., Bhattacharya, A. and Frery, A.C., 2019. A Generalized Volume Scattering Model-Based Vegetation Index From Polarimetric SAR Data. IEEE Geoscience and Remote Sensing Letters. vol. 16, no. 11, pp. 1791-1795, Nov. 2019.
https://doi.org/10.1109/LGRS.2019.2907703

Remote Sensing of Environment 237 (2020) 111561

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

Assessment of rice growth conditions in a semi-arid region of India using the Generalized Radar Vegetation Index derived from RADARSAT-2 polarimetric SAR data

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ARTICLE INFO

Edited by Marie Weiss

Keywords:
Rice
GRVI
SAR polarimetry
Direct seeded rice
RVI

ABSTRACT

Rice growth monitoring using Synthetic Aperture Radar (SAR) is recognized as a promising approach for tracking the development of this important crop. Accurate spatio-temporal information of rice inventories is required for water resource management, production risk occurrence, and yield forecasting. This research investigates the potential of the proposed Generalized volume scattering model based Radar Vegetation Index (GRVI) for monitoring rice growth at different phenological stages. The GRVI is derived using the concept of a geodesic distance (GD) between Kennaugh matrices projected on a unit sphere. We utilized this concept of GD to quantify a similarity measure between the observed Kennaugh matrix (representation of observed Polarimetric SAR information) and the Kennaugh matrix of a generalized volume scattering model (a realization of scattering media). The similarity measure is then modulated with a factor estimated from the ratio of the minimum to the maximum GD between the observed Kennaugh matrix and the set of elementary targets: trihedral, cylinder, dihedral, and narrow dihedral. In this work, we utilize a time series of C-band quad-pol RADARSAT-2 observations over a semi-arid region in Vijayawada, India. Among the several rice cultivation practices adopted in this region, we analyze the growth stages of direct seeded rice (DSR) and conventional tansplanted rice (TR) with the GRVI and crop biophysical parameters viz., Plant Area Index – PAI. The GRVI is compared for both rice types against the Radar Vegetation Index (RVI) proposed by Kim and van Zyl. A temporal analysis of the GRVI with crop biophysical parameters at different phenological stages confirms its trend with the plant growth stages. Also, the linear regression analysis confirms that the GRVI outperforms RVI with significant correlations with PAI ($r \geq 0.83$ for both DSR and TR). In addition, PAI estimations from GRVI show promising retrieval accuracy with Root Mean Square Error (RMSE) < $1.05 m^2\ m^{-2}$ and Mean Absolute Error (MAE) < $0.85 m^2\ m^{-2}$.

1. Introduction

Rice (*Oryza sativa*) is the major crop grown in the Indian subcontinent of Asia. The majority of the rice cultivars are grown during the monsoon season (July to November), i.e., *Kharif* season. Despite available rain, in many regions, rice production is significantly affected

Integrated Crop Management (ICM) government policies in the semi-arid region of these districts (APAgriculture, 2018; NIBIO, 2012).

Rice production strongly depends on the crop establishment period, which affects the critical phenological stages (tillering, flowering, and grain filling periods) (Lampayan et al., 2015; Mahajan et al., 2009). Thus, it is essential to monitor the temporal dynamics of plant growth

Mandal, D., Kumar, V., Ratha, D., Lopez-Sanchez, J.M., Bhattacharya, A., McNairn, H., Rao, Y.S. and Ramana, K.V., 2020. Assessment of rice growth conditions in a semi-arid region of India using the Generalized Radar Vegetation Index derived from RADARSAT-2 polarimetric SAR data. Remote Sensing of Environment, 237, p.111561. https://doi.org/10.1016/j.rse.2019.111561