



# NARAYANARAO BHOGAPURAPU

PhD., Geoinformatics (ongoing)

☎ +91 7799577546 ✉ [bnarayanarao@iitb.ac.in](mailto:bnarayanarao@iitb.ac.in)



## PROFILE

My work focuses on the advancements and applicability of Synthetic Aperture Radar (SAR) polarimetric parameters to estimate soil moisture over croplands. In my work, I have devised a novel methodology to estimate soil moisture over croplands solely using dual-pol GRD SAR data. The advantages of this method include continuous monitoring of soil moisture over a larger scale at higher resolutions. Besides, I have also developed a novel methodology to estimate soil moisture using full and compact polarimetric SAR data. On the other hand, monitoring and quantifying vegetation content directly helps in better estimation of soil moisture. In this regard, I have developed different vegetation descriptors for dual-pol GRD SAR data. Besides, these descriptors are also capable of estimating crop biophysical parameters. These techniques are successfully implemented using Amazon Web Services (AWS), Google Earth Engine (GEE) and Google Colaboratory (Google Colab). These novel techniques and strategies might be helpful to develop operational agricultural crop monitoring platforms through the Joint Experiment for Crop Assessment and Monitoring (JECAM) international research network as well as upcoming satellite missions. My career objective is to obtain a researcher position in the field of remote sensing application to agriculture to associate myself with a progressing science and the nation. Besides, I want to put my expertise to the best use for the remote sensing and agricultural community, as well as widening my technical spectrum.

## EDUCATION

### Ph.D. in Geoinformatics and Natural Resources Engineering

2018 - present

Institute: Indian Institute of Technology Bombay, Mumbai, India.

Thesis title: Soil moisture retrieval over croplands using SAR data

Advisors: Prof. Y.S.Rao & Prof. Avik Bhattacharya

CPI: 9.43/10.0

### M.Tech. in Remote sensing and GIS

2016 - 2018

Institute: National Institute of Technology Warangal, India

Thesis title: Subsurface physical parameters sensitivity analysis using GPR modelling and simulations

Advisor: Prof. K. V. Reddy & D. K. Pandey

CPI: 8.95/10.0

### B.E. in Civil Engineering

2012 - 2016

Institute: Andhra University, India

Thesis title: Analysis of multi-storied office building (manual design)

Advisor: Prof. K. Santosh Kumar

CGPA : 8.45/10

### Higher secondary (10+2) Science

2005 - 2012

School: Jawahar Navodaya Vidhyalaya, Kiltampalem, India

Marks: 84.8 %

## PUBLICATIONS

**Google Scholar profile:** <https://scholar.google.co.in/citations?user=-OryAUAAAAAJ&hl=en>

**ORCID:** <https://orcid.org/0000-0002-6496-7283>

**Citation:** 46; h-index: 4; i10-index: 1 (records based on Google scholar 30 March, 2022)

### Peer Review Journal Articles:

- [J8] Narayanarao Bhogapurapu, Subhadip Dey, Saeid Homayouni, Avik Bhattacharya, and Y. S. Rao 2022 “Field-Scale Soil Moisture Estimation Using Sentinel-1 GRD SAR Data ”, *Advances in Space Research*.
- [J7] Swarnendu Sekhar Ghosh, Subhadip Dey, Narayanarao Bhogapurapu, Saeid Homayouni, Avik Bhattacharya, and Heather McNairn 2022 “Gaussian process regression model for crop biophysical parameter retrieval from multi-polarized C-band SAR data ”, *Remote sensing*. 14(4):934.
- [J6] Narayanarao Bhogapurapu, Subhadip Dey, Dipankar Mandal, Avik Bhattacharya, L. Karthikeyan, Heather McNairn and Y. S. Rao 2022 “Soil Moisture Retrieval Over Croplands Using dual-pol L-band GRD SAR Data ”, *Remote Sensing of Environment*. 271, p.112900.

- [J5] Subhadip Dey, **Narayanarao Bhogapurapu**, Saeid Homayouni, Avik Bhattacharya, and Heather McNairn 2021 “Unsupervised Classification of Crop Growth Stages with Scattering Parameters from Dual-Pol Sentinel-1 SAR Data”, *Remote Sensing*, 2021, 13, 4412.
- [J4] Subhadip Dey, Ushasi Chaudhuri, **Narayanarao Bhogapurapu**, Juan Lopez-Sanchez, Biplab Banerjee, Avik Bhattacharya, Dipankar Mandal, and Y. S. Rao 2021 “Synergistic Use of TanDEM-X and Landsat-8 Data for Crop-type Classification and Monitoring”, *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 14, pp.8744-8760.
- [J3] **Narayanarao Bhogapurapu**, Subhadip Dey, Avik Bhattacharya, Dipankar Mandal, Juan Lopez-Sanchez, Heather McNairn, Carlos López-Martínez and Y. S. Rao 2021 “Dual-polarimetric descriptors from Sentinel-1 GRD SAR data for crop growth assessment”, *ISPRS Journal of Photogrammetry and Remote Sensing* 178 (2021): 20-35.
- [J2] Subhadip Dey, **Narayanarao Bhogapurapu**, Avik Bhattacharya, Dipankar Mandal, Juan Lopez-Sanchez, Heather McNairn, and Alejandro C. Frery 2021 “Rice Phenology Mapping Using Novel Target Characterization Parameters from Polarimetric SAR Data”, *International Journal of Remote Sensing*, 42:14, 5519-5543,
- [J1] **Narayanarao Bhogapurapu**, Subhadip Dey, Dipankar Mandal, Avik Bhattacharya and Y. S. Rao 2021 “PolSAR tools: A QGIS plugin for generating SAR descriptors.”, *Journal of Open Source Software*, 6(60), 2970.

#### Conference Proceedings:

- [C15] **Narayanarao Bhogapurapu**, Subhadip Dey, Avik Bhattacharya, Carlos López-Martínez, Irena Hajnsek and Y. S. Rao 2022 “Soil permittivity estimation over croplands using PolSAR data”, *Geoscience and Remote Sensing Symposium (IGARSS)*, *IEEE International* (Accepted).
- [C14] **Narayanarao Bhogapurapu**, S. Dey, Saeid Homayouni, A. Bhattacharya, and Y. S. Rao 2022 “Scattering Parameters from Sentinel-1 SAR Data for crop growth assessment”, *IEEE Mediterranean and Middle-East Geoscience and Remote Sensing Symposium (M2GARSS)*, *IEEE International*.
- [C13] Swarnendu Sekhar Ghosh, S. Dey, **Narayanarao Bhogapurapu**, Saeid Homayouni, A. Bhattacharya, and Heather McNairn 2022 “Crop biophysical parameter retrieval using Gaussian process regression from C-band polarimetric SAR data”, *IEEE Mediterranean and Middle-East Geoscience and Remote Sensing Symposium (M2GARSS)*, *IEEE International*.
- [C12] **Narayanarao Bhogapurapu**, S. Dey, A. Verma, A. Bhattacharya, Carlos López-Martínez and P. Pankajakshan 2021 “Crop growth assessment using Sentinel-1 GRD SAR descriptors”, *IEEE India Geoscience and Remote Sensing Symposium (InGARSS)*, *IEEE International*.
- [C11] S. Dey, **Narayanarao Bhogapurapu**, A. Verma, Saeid Homayouni, Carlos López-Martínez, and A. Bhattacharya 2021 “Simultaneous evaluation of the target scattering-type parameter and scattering power components from polarimetric SAR images”, *IEEE India Geoscience and Remote Sensing Symposium (InGARSS)*, *IEEE International*.
- [C10] A. Verma, S. Dey, **Narayanarao Bhogapurapu**, Carlos López-Martínez, and A. Bhattacharya 2021 “Dual polarimetric SAR signature for human-made target characterization”, *IEEE India Geoscience and Remote Sensing Symposium (InGARSS)*, *IEEE International*.
- [C9] **Narayanarao Bhogapurapu**, Subhadip Dey, Avik Bhattacharya, and Y. S. Rao 2021 “Soil Moisture Estimation Using Simulated NISAR Dual Polarimetric GRD Product over Croplands”, *APSAR 2021: The 7th Asia-Pacific Conference on Synthetic Aperture Radar*.
- [C8] Subhadip Dey, **Narayanarao Bhogapurapu**, Avik Bhattacharya, Dipankar Mandal, Heather McNairn and Y. S. Rao 2021 “Novel Clustering Technique for Monitoring Crop Phenology”, *APSAR 2021: The 7th Asia-Pacific Conference on Synthetic Aperture Radar*.
- [C7] **Narayanarao Bhogapurapu**, Avik Bhattacharya, and Y. S. Rao 2021 “Chandrayaan-2 Dual Frequency Synthetic Aperture Radar (DFSAR) Full and Compact Polarimetric Data Analysis for the Lunar Surface”, *APSAR 2021: The 7th Asia-Pacific Conference on Synthetic Aperture Radar*.
- [C6] **Narayanarao Bhogapurapu**, Subhadip Dey, Dipankar Mandal, Avik Bhattacharya and Y. S. Rao 2021 “Monitoring wheat crop growth using a new vegetation index from Sentinel-1 GRD SAR data”, *Geoscience and Remote Sensing Symposium (IGARSS)*, *IEEE International*.
- [C5] Subhadip Dey, **Narayanarao Bhogapurapu**, Avik Bhattacharya, Alejandro C. Frery, and Paolo Gamba 2021 “Built-up area mapping using full and dual polarimetric SAR data”, *Geoscience and Remote Sensing Symposium (IGARSS)*, *IEEE International*.
- [C4] Abhinav Verma, Subhadip Dey, **Narayanarao Bhogapurapu**, Dipankar Mandal, Dipanwita Haldar, Avik Bhattacharya 2021 “Polarimetric SAR Signature for Crop Characterization”, *Geoscience and Remote Sensing Symposium (IGARSS)*, *IEEE International*.

- [C3] **Narayanarao Bhogapurapu**, Dipankar Mandal, Y. S. Rao and Avik Bhattacharya 2020 “Soil Moisture retrieval using SAR derived vegetation descriptors in water cloud model”, *Geoscience and Remote Sensing Symposium (IGARSS), IEEE International*.
- [C2] **Narayanarao Bhogapurapu**, Dipankar Mandal, Y. S. Rao and Avik Bhattacharya 2020 “Soil moisture estimation for wheat crop using dual-pol L-band SAR data”, *IEEE India Geoscience and Remote Sensing Symposium (InGARSS), IEEE International*.
- [C1] Dipankar Mandal, **Narayana Rao Bhogapurapu**, Vineet Kumar, Subhadip Dey, Debanshu Ratha, Avik Bhattacharya, Juan M. Lopez-Sanchez, Heather McNairn, Y. S. Rao 2020 “Vegetation monitoring using a new dual-pol radar vegetation index: A preliminary study with simulated NASA-ISRO SAR (NISAR) L-band data”, *Geoscience and Remote Sensing Symposium (IGARSS), IEEE International*.

#### Workshops/Presentations:

- [W2] **Narayanarao Bhogapurapu**, Subhadip Dey, Avik Bhattacharya, and Y. S. Rao 2021 “Soil moisture estimation over canola crop using Simulated NISAR Dual Polarimetric GRD Product”, *PolInSAR 2021: The 10th International Workshop on Science and Applications of SAR Polarimetry and Polarimetric Interferometry*.
- [W1] Subhadip Dey, **Narayanarao Bhogapurapu**, Avik Bhattacharya, and Y. S. Rao 2021 “Crop Monitoring Using Sentinel-1 GRD Product in GEE Platform”, *PolInSAR 2021: The 10th International Workshop on Science and Applications of SAR Polarimetry and Polarimetric Interferometry*.

#### Book Chapter:

- [BC1] **Narayana Rao Bhogapurapu**, Pandey, D.K., Reddy, K.V. and Putrevu, D., 2020. “Study of Subsurface Roughness Impact on GPR Performance Using Modelling and Simulation”, *In Applications of Geomatics in Civil Engineering* (pp. 471-477). Springer, Singapore.

### PRODUCT DEVELOPMENT AND TECHNOLOGY TRANSFER

- o **Dual-pol descriptors Google Earth Engine app:** [https://github.com/Narayana-Rao/dual\\_pol\\_descriptors](https://github.com/Narayana-Rao/dual_pol_descriptors) 2021
- o **PolSAR tools-QGIS Plugin** [https://plugins.qgis.org/plugins/polsar\\_tools/](https://plugins.qgis.org/plugins/polsar_tools/) 2021
- o **Soil moisture estimation code for dual-pol SAR data** - EO-browser Custom script contest shortlisted 2019

### RESEARCH INTERESTS

- Soil moisture estimation over croplands using PolSAR data
- SAR Polarimetry, quad, compact and dual polarimetric data
- Crop monitoring and biophysical parameter estimation
- Big data analytics and cloud based platforms for global agriculture monitoring and soil moisture estimation

### RESEARCH PROJECTS/ THIRD PARTY FUNDING ACQUIRED

| Acquired Funding | Funding Agency   | Project Duration  | Project Title  | Role in the Project | Remarks   |
|------------------|--|-------------------|--|---------------------|---|
| €66000           | Group on Earth Observations (GEO) and Amazon Web Services (AWS)  | JUN/2019-JUN/2022 | AWS4AgriSAR: Crop Inventory Mapping from SAR Data on Cloud Computing Platform<br>Link: <a href="http://www.earthobservations.org/article.php?id=362">http://www.earthobservations.org/article.php?id=362</a>   | Team member         | This research grant was through the GEO-Amazon Earth Observation Cloud Credits Programme  |
| €0               | GEO Global Agricultural Monitoring (GEOGLAM) / Joint Experiment for Crop Assessment and Monitoring (JECAM) | JUN/2017-JUN/2020 | JECAM SAR Inter-Comparison Experiment: Crop Type Identification & Mapping and crop biophysical parameter retrieval<br>Link: <a href="http://jecam.org/experiment/sar-intercomparison/">http://jecam.org/experiment/sar-intercomparison/</a><br><a href="http://jecam.org/studysite/india-vijayawada/">http://jecam.org/studysite/india-vijayawada/</a> | Team member         | JECAM network provided numerous Earth Observation datasets free of charge to the partners through agreement with Canadian Space Agency. |

### TECHNICAL SKILLS

|                       |   |
|-----------------------|---|
| Programming Skill     | C   C++   Python   MATLAB   R   JS                                      |
| Software and Tools    | ArcGIS   QGIS   ERDAS Imagine   ENVI   Autocad   PolSARPro   SNAP   Git |
| Python packages       | GDAL   Rasterio   Geopandas   Spectral   Pandas   PYRAT   Scipy   Numpy |
| Cloud based platforms | Google Earth Engine   Amazon Web services (AWS)   Google cloud platform |
|                       | Multi-Mission Algorithm and Analysis Platform (NASA MAAP)               |

## FIELD EXPEDITIONS/ CAMAPIGNS

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|--|---------------------|
| Co-lead the Field Campaign with joint collaboration by MRSLab – IIT Bombay, and APSAC, at JECAM Test site in Andhra Pradesh, India. The aim of this campaign was to collect Crop and Soil parameters in synchronous with Satellite (Radarsat-2, TerraSAR-X, ALOS-2, Sentinel-1A, Sentinel-2) overpasses. | Jun 2019 - Dec 2019 |
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## TEACHING EXPERIENCE

### Institute: CSRE, Indian Institute of Technology Bombay, India

| Title of course taught  | Level:<br>Postgraduate/<br>Undergraduate | Role: Instructor/<br>Teaching Assistant<br>(TA) | Year - session |
|---|--|---|----------------|
| GNR647: Microwave Remote Sensing                                  | Postgraduate                             | TA  | 2021 - Spring  |
| GNR617: Image Interpretation Laboratory                           | Postgraduate                             | TA  | 2021 - Spring  |
| GNR647: Microwave Remote Sensing                                  | Postgraduate                             | TA  | 2020 - Spring  |
| GNR792: Communications Skills                                     | Postgraduate                             | TA  | 2020 - Autumn  |
| GNR617: Image Interpretation Laboratory                           | Postgraduate                             | TA  | 2020 - Autumn  |
| GNR621: Natural Resources: Hydrosphere, Cryosphere and Atmosphere | Postgraduate                             | TA  | 2020 - Autumn  |
| GNR401: Remote sensing and Image Processing                       | Postgraduate                             | TA  | 2020 - Autumn  |

## EXPERIENCE

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| <b>Microwave Remote Sensing Laboratory, UMass Amherst   United States</b><br>Designation: <b>Visiting research scholar</b> | Jan 2022 - Present |
|--|--------------------|

- Forest height estimation using InSAR and LiDAR techniques

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|--|----------------------|
| <b>CropIn Technology Solutions   India</b><br>Designation: <b>Earth Observation Fellow</b> | July 2021 - Dec 2021 |
|--|----------------------|

- Soil moisture estimation and crop monitoring using dual polarimetric SAR data
- Large scale soil moisture mapping and crop monitoring using Sentinel-1 GRD SAR data and cloud based platforms

|  |                |
|--|----------------|
| <b>Indian Institute of Technology Bombay   Microwave Remote Sensing Lab, India</b><br>Designation: <b>Research Scholar</b> | 2019 - present |
|--|----------------|

- Soil moisture estimation and crop monitoring using PolSAR data
- Global soil moisture mapping and crop monitoring using GRD SAR data and cloud based platforms

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|---|----------------|
| <b>Indian Institute of Technology Bombay   Centre of Studies in Resources Engineering</b><br>Designation: <b>Teaching Assistant</b> | 2019 - present |
|---|----------------|

- Courses involvement:  
**GNR647:** Microwave Remote Sensing | **GNR805:** Advanced Concepts in Polarimetric SAR Image Analysis | **GNR617:** Image Interpretation Laboratory | **GNR792:** Communications Skills | **GNR621:** Natural Resources: Hydrosphere, Cryosphere and Atmosphere

|   |                      |
|---|----------------------|
| <b>Masters In-Plant Training</b><br>Designation: <b>Trainee</b><br>Institute/organization: Space Applications centre (ISRO), Ahmedabad<br>Description: Subsurface physical parameters sensitivity analysis using Ground Penetrating Radar modelling and simulations | July 2017 - May 2018 |
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## SYNERGISTIC ACTIVITY

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### Peer Recognition:

Verified Publons account: <https://publons.com/researcher/4144298/narayanarao-bhogapurapu/>

- Session manager in sessions: MO2.R6, TU2.R15, WE1.R1, WE2.R10, THU2.R15, FR2.R5 in IEEE International Geoscience and Remote Sensing Symposium-IGARSS 2020, Hawaii, United States of America.
- Session manager in sessions: WE1.R2, FR2.R1 in IEEE International India Geoscience and Remote Sensing Symposium 2020, Gujarat, India.
- Session manager in sessions: Tutorial HD-3, Young Professional Events, FR2.H2 in IEEE International India Geoscience and Remote Sensing Symposium 2021, Gujarat, India.

### Professional Membership:

- IEEE Geoscience and Remote Sensing Society (S'19)
- Indian Society of Remote Sensing (Life Member'21 – L-5619)

### Reviewer: Journals/Conferences/Projects

- Journal: Remote Sensing of Environment, IEEE Geoscience and Remote Sensing Letters, IEE Access, Journal of Open Source Software, Progress In Electromagnetics Research
- Conference: ICETCI 2021 : International Conference on Emerging Techniques in Computational Intelligence, M2GARSS 2022: IEEE Mediterranean and Middle-East Geoscience and Remote Sensing Symposium

## FELLOWSHIPS & AWARDS

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| Name of award  | Description  | Year                 |
|--|--|----------------------|
| Visiting Scholar Fellowship                          | This competitive fellowship award is provided by the University of Massachusetts Amherst, United States, under the NISAR project.  | Jan 2022 - Present   |
| Earth Observation Fellowship                         | This competitive fellowship award is provided by the Cropin Technology Solutions Pvt. Ltd. India   | July 2021 - Dec 2021 |
| Shortlisted as EO-browser Custom script contest 2019 | Sentinel-hub and the Copernicus EU Earth Observation programme and the European Space Agency organized EO-browser custom script contest for globally scripting hackathon | 2020                 |
| Ph.D. Assistantship                                  | This competitive fellowship award is provided by the Ministry of Human Resource Development, Government of India   | 2019 - Present       |
| M.Tech Assistantship                                 | This competitive fellowship award is provided by the Ministry of Human Resource Development, Government of India   | 2016 - 2018          |
| Post-matric Scholarship                              | This competitive sponsorship award is provided by the Government of Andhra Pradesh, India  | 2012 - 2016          |