NARAYANARAO BHOGAPURAPU

PhD., Geoinformatics and Natural Resources Engineering (ongoing)

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PROFILE

My work focuses on the advancements and applicability of Polarimetric Synthetic Aperture Radar (SAR) techniques for crop monitoring and soil moisture estimation. 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 help better estimate 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 in developing 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 and forestry 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, agricultural, and forest ecosystems community, as well as widen my technical spectrum.

EDUCATION

Ph.D. in Geoinformatics and Natural Resources Engineering 2019 - 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
University: 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 | ORCID | Publons

Citation: 117; h-index: 5; i10-index: 5 (records based on Google scholar 2 April 2023)

Peer Review Journal Articles:

[J9] **N. Bhogapurapu**, S. Dey, A. Bhattacharya, C. López-Martínez, I. Hajnsek, and Y. S. Rao 2022 "Soil Permittivity Estimation Over Croplands Using Full and Compact Polarimetric SAR Data ", *IEEE Transactions on Geoscience and Remote Sensing*, 60, pp. 1-17.

[J8] **N. Bhogapurapu**, S. Dey, S. Homayouni, A. Bhattacharya, and Y. S. Rao 2022 "Field-Scale Soil Moisture Estimation Using Sentinel-1 GRD SAR Data ", *Advances in Space Research*, 70, 3845–3858.

[J7] S. S. Ghosh, S. Dey, **N. Bhogapurapu**, S. Homayouni, A. Bhattacharya, and H. McNairn 2022 "Gaussian process regression model for crop biophysical parameter retrieval from multi-polarized C-band SAR data ", *Remote sensing*. 14(4):934.

[J6] **N. Bhogapurapu**, S. Dey, D. Mandal, A. Bhattacharya, L. Karthikeyan, H. 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] S. Dey, **N. Bhogapurapu**, S. Homayouni, A. Bhattacharya, and H. McNairn 2021 "Unsupervised Classification of Crop Growth Stages with Scattering Parameters from Dual-Pol Sentinel-1 SAR Data ", *Remote Sensing*, 2021, 13, 4412.

[J4] S. Dey, U. Chaudhuri, **N. Bhogapurapu**, J. Lopez-Sanchez, B. Banerjee, A. Bhattacharya, D. 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] **N. Bhogapurapu**, S. Dey, A. Bhattacharya, D. Mandal, J. Lopez-Sanchez, H. McNairn, C. 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] S. Dey, **N. Bhogapurapu**, A. Bhattacharya, D. Mandal, J. Lopez-Sanchez, H. McNairn, and A. 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] **N. Bhogapurapu**, S. Dey, D. Mandal, A. 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:

[C17] S. S. Ghosh, **N. Bhogapurapu**, A. Bhattacharya, and S. Homayouni 2023 "Enhancing Gaussian Processes Retrieval of Plant Area Index Utilizing Dual-Polarimetric Pseudo Entropy (Hc) ", *Machine Intelligence for GeoAnalytics and Remote Sensing (MIGARS 2023)*.

[C16] S. Dey, **N. Bhogapurapu**, and A. Bhattacharya 2022 "Ground and Volume Scattering Separation in Compact Polarimetric Interferometric SAR Data ", *URSI Regional Conference on Radio Science (URSI-RCRS 2022)*.

[C15] **N. Bhogapurapu**, S. Dey, A. Bhattacharya, C. López-Martínez, I. Hajnsek, and Y. S. Rao 2022 "Soil permittivity estimation over croplands using PolSAR data", *Geoscience and Remote Sensing Symposium (IGARSS), IEEE International* (**Student Paper competition winner**).

[C14] **N. 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] S. S. Ghosh, S. Dey, **N. Bhogapurapu**, S. Homayouni, A. Bhattacharya, and H. 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] **N. Bhogapurapu**, S. Dey, A. Verma, A. Bhattacharya, C. 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, **N. Bhogapurapu**, A. Verma, S. Homayouni, C. 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, **N. Bhogapurapu**, C. 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] **N. Bhogapurapu**, S. Dey, A. 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] S. Dey, **N. Bhogapurapu**, A. Bhattacharya, D. Mandal, H. 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] **N. Bhogapurapu**, A. 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] **N. Bhogapurapu**, S. Dey, D. Mandal, A. 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] S. Dey, **N. Bhogapurapu**, A. 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] A. Verma, S. Dey, **N. Bhogapurapu**, D. Mandal, D. Haldar, A. Bhattacharya 2021 "Polarimetric SAR Signature for Crop Characterization ", *Geoscience and Remote Sensing Symposium (IGARSS), IEEE International.*

[C3] **N. Bhogapurapu**, D. Mandal, Y. S. Rao and A. Bhattacharya 2020 "Soil Moisture retrieval using SAR derived vegetation descriptors in water could model", *Geoscience and Remote Sensing Symposium (IGARSS), IEEE International.*

[C2] **N. Bhogapurapu**, D. Mandal, Y. S. Rao and A. 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] D. Mandal, **N. R. Bhogapurapu**, V. Kumar, S. Dey, D. Ratha, A. Bhattacharya, J. M. Lopez-Sanchez, H. 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/Talks:

[W5] **N. Bhogapurapu**, P. Siqueira, J. Armston, Xiaoxuan Li, K. Wessels, L. Duncanson 2022 " Temporal analysis of C-band InSAR decorrelation for canopy height mapping over dry forests and tropical savannas ", *AGU Fall Meeting 2022.*

[W4] **N. Bhogapurapu**, Paul Siqueira, John Armston, Xiaoxuan Li, Konrad Wessels, Laura Duncanson 2022 " Sentinel-1 decorrelation for forest canopy height estimation over dry forests and tropical savannas ", *October 2022 NISAR Science Team Meeting, Boston, USA.*

[W3] **N. Bhogapurapu**, Paul Siqueira, John Armston, Xiaoxuan Li, Konrad Wessels, Laura Duncanson 2022 " Sentinel-1 C-band InSAR temporal decorrelation analysis over dry tropical savannas and other forests ", *2022 NISAR Science Community Workshop, Pasadena, USA.*

[W2] **N. Bhogapurapu**, S. Dey, A. 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] S. Dey, **N. Bhogapurapu**, A. 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] **N. R. 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

- **PolSARtools PyPI package** hhttps://pypi.org/project/polsartools/ 2022
- **Dual-pol descriptors Google Earth Engine app:** https://github.com/Narayana-Rao/dual_pol_descriptors 2021
- **PolSAR tools-QGIS Plugin** https://plugins.qgis.org/plugins/polsar_tools/ 2021
- **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, forest monitoring and biophysical parameter estimation
- Big data analytics and cloud-based platforms for global agriculture, forest monitoring and soil moisture estimation

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)

RESEARCH PROJECTS/ THIRD PARTY FUNDING ACQUIRED

Acquired Funding	Funding Agency	Project Duration	Project Title	Role in the Project	Remarks
$ 120000	Group on Earth Observations (GEO) and Microsoft Planetary Computer Programme	JUN/2022-JUN/2025	Azure4GEO - Deep learning based crop characterization with synergistic use of SAR and optical data on cloud computing platform	Team member	This research grant was through the GEO-Microsoft Planetary Computer Programme Programme
$ 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 Link: http://www.earthobservations.org/article.php?id=362	Team member	This research grant was through the GEO-Amazon Earth Observation Cloud Credits Programme
–	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 Link: http://jecam.org/experiment/sar-intercomparison/ http://jecam.org/studysite/india-vijayawada/	Team member	JECAM network provided numerous Earth Observation datasets free of charge to the partners through agreement with Canadian Space Agency.

FIELD EXPEDITIONS/ CAMAPIGNS

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

Volunteered the SMAPVEX-2022 field Campaign with joint collaboration by NASA JPL, USDA and MIRSL-UMass, at Harvard Forest Test site in Massachusetts, USA. The aim of this campaign was to collect Forest canopy and Soil parameters in synchronous with Satellite (SMAP, Sentinel-1A) overpasses. April 2022

TEACHING EXPERIENCE

Institute: CSRE, Indian Institute of Technology Bombay, India

Title of course taught	Level: Postgraduate/ Undergraduate	Role: Instructor/ Teaching Assistant (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

Microwave Remote Sensing Laboratory, UMass Amherst | United States Jan 2022 - Present
Designation: **Visiting research scholar**

- Forest height estimation using InSAR and LiDAR data

CropIn Technology Solutions | India July 2021 - Dec 2021
Designation: **Earth Observation Fellow**

- 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

Indian Institute of Technology Bombay | Microwave Remote Sensing Lab, India 2019 - present
Designation: **Research Scholar**

- Soil moisture estimation and crop monitoring using PolSAR data

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

Indian Institute of Technology Bombay | Centre of Studies in Resources Engineering 2019 - present
Designation: **Teaching Assistant**

- 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

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

FELLOWSHIPS, GRANTS & AWARDS

Name of award	Description	Year
Mikio Takagi Student Prize	This prestigious award is given to a student who has presented an outstanding paper at the IEEE Geoscience and Remote Sensing Symposium (IGARSS).	July 2022
IEEE GRSS Travel Grant	This grant is awarded by IEEE GRSS society to support the travel for participating in the IEEE Geoscience and Remote Sensing Symposium (IGARSS).	July 2022
Visiting Scholar Fellowship	This competitive fellowship award is provided by the University of Massachusetts Amherst, United States, under the NISAR project.	Jan 2022 - Present
Shortlisted for Fulbright-Nehru Doctoral Research Fellowship	This competitive fellowship award is provided by United States – India Educational Foundation (USIEF).	2022
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, the Government of India	2019 - Present
M.Tech Assistantship	This competitive fellowship award is provided by the Ministry of Human Resource Development, the Government of India	2016 - 2018
Post-matric Scholarship	This competitive sponsorship award is provided by the Government of Andhra Pradesh, India	2012 - 2016

SYNERGISTIC ACTIVITY

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:

- American Geophysical Union (S'22)
- IEEE Geoscience and Remote Sensing Society (S'19)
- Indian Society of Remote Sensing (Life Member'21)

Reviewer: Journals/Conferences/Projects

- Journal: Remote Sensing of Environment, International Journal of Remote Sensing, IEEE Geoscience and Remote Sensing Letters, IEEE 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