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Journal of Ecology and Natural Resources
ISSN: 2578-4994

Advancing Ecosystem Monitoring and Management through Synthetic Aperture Radar (SAR) Remote Sensing

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Commentary
Volume 8 Issue 3
Received Date: August 15, 2024
Published Date: September 23, 2024
DOI: 10.23880/jenr-16000392

Commentary

As a new member of the Editorial Board for the Journal of Ecology & Natural Resources (JENR), I am delighted to be invited to share my views on how Synthetic Aperture Radar (SAR) Remote Sensing could advance ecosystem monitoring and management. SAR remote sensing has emerged as a powerful tool in ecological research, providing critical insights into ecosystem dynamics. SAR operates effectively under all weather conditions and during both day and night, making it an excellent complementary tool to optical satellites images like the Landsat series and Sentinel-2 [1,2]. SAR offers various types of time-series information for earth observation, including SAR backscatter energy intensity (amplitude) time-series, InSAR coherence time-series, and InSAR elevation change time-series. In this commentary, I will focus on the application of SAR amplitude time-series change detection in ecosystem monitoring. Finally, I will introduce the application of SAR phase for mapping floodplain subsidence and river sediment aggradation rates, enhancing flood risk modelling and ecosystem impact assessment.

Flood Inundation Detection

Flooding poses significant risks to ecosystems, affecting both terrestrial and aquatic habitats. SAR amplitude time-series can provide timely information on flood extent and duration, essential for flood risk response. SAR's capability to detect surface water extent through SAR amplitude changes is well-documented in studies like [3]. A recent development of HydroSAR is designed to monitor flooding events using Sentinel-1 SAR data in the Hindu Kush Himalaya region [4]. The algorithms used in HydroSAR are assessed for accuracy, with flood extent mapping showing over 90% accuracy and water depth measurement accuracy within 1 meter.

Soil Moisture Variation

Soil moisture is key to understanding hydrological processes and vegetation health. SAR's sensitivity to the dielectric properties of soil moisture has been explored in numerous studies, including [5,6]. Utilizing SAR amplitude time-series, researchers can monitor soil moisture dynamics across large spatial scales, informing agricultural practices, drought management, and climate models. The high temporal resolution of SAR satellite revisit times allows for continuous monitoring, capturing both seasonal and year-to-year soil moisture variations.

Crop Monitoring

SAR amplitude is sensitive to crop moisture and the geometry of canopy roughness. These characteristics are leveraged in agricultural monitoring to determine crop types, locations, and growth cycles globally [7]. This is crucial for optimizing resource use, improving global food security. However, the interactions of SAR with crop structure and moisture are complex and often difficult to understand. Modelling may be required for better interpretation of SAR amplitude time-series for crop growth monitoring.

Deforestation Monitoring

Deforestation and reforestation are critical processes influencing biodiversity, carbon cycles [8], and climate regulation. High-impact studies, such as [9,10] have demonstrated SAR's effectiveness in tracking forest biomass changes. By analysing SAR time-series data, researchers

can accurately assess deforestation rates and reforestation efforts, aiding in the development of conservation strategies and policy-making [11].

Floodplain subsidence and river sediment aggradation rate mapping

Based on the SAR phase, we can map surface elevation change time-series [12]. Subsidence is a widespread process where the Earth's surface sinks due to natural and human-induced factors [13,14]. I am currently working on mapping river sediment aggradation rates to understand the impact of increased flood risk on ecosystems, including sediment/soil nutrient cycling, floodplain irrigation, the effects of flood inundation on crops, and sustainable agriculture.

Open source toolbox on SAR amplitude time-series analysis with Sentinel-1 SAR data

The Sentinel constellation offers a great resource of free remote sensing data. Open source tools are also essential for fully exploring the potential of SAR products and conducting reproducible research data analysis. Here a few open-source toolboxes that perform SAR time-series analysis.

- SAR intensity and coherence time-series plot notebook from University of Edinburgh

https://zenodo.org/doi/10.5281/zenodo.13222093

- HydroSAR flood extent and depth mapping notebook from ASF Open SAR Lab

https://github.com/ASFOpenSARlab/opensarlab-notebooks/tree/master/SAR_Training/English/HydroSAR

Conclusion

At the end, I want to express my personal view on the interdisciplinary nature of SAR remote sensing. Yes, SAR is indeed a powerful tool to detect changes in flood dynamics, soil monitoring, crops, forests, even sinking earth and aggraded riverbeds. However, each subject cannot be fully understood solely through SAR remote sensing due to the complexity of natural and anthropogenic effects on the Earth. This means we need expertise in fields such as hydrology, geomorphology, phenology, ecology, software engineering, and so on, in addition to being SAR experts. This challenge could be addressed through effective interdisciplinary collaboration with respect and understanding.

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