Early-spring vegetation dynamics in deciduous forests revealed by Sentinel-1 radar and ground phenological observations

M. Majchrzak, P. Bogawski*

*Department of Systematics and Environmental Botany, Faculty of Biology, Adam Mickiewicz University in Poznań, Uniwersytetu Poznańskiego 6, 61-614 Poznań, Poland, *magdalena.majchrzak@amu.edu.pl*

Keywords: spring phenology, radar remote sensing, forest structure, deciduous forests, Sentinel-1

Plant phenology plays a key role in the functioning of forest ecosystems. The start of the growing season marks the transition from winter dormancy to intensive biological activity and influences primary production, carbon cycling and the seasonal availability of food resources for other organisms. In deciduous forests, vegetation development in spring occurs gradually across successive layers of the ecosystem, from the forest floor and understory to the tree canopy. Traditional ground-based phenological observations provide detailed information about these processes; however, their spatial coverage is limited. Satellite remote sensing enables the monitoring of phenological changes over large areas. Currently, optical satellite data are most commonly used for this purpose, but their availability may be limited by frequent cloud cover in early spring, a period when phenological changes occur most rapidly. In addition, optical signals integrate information from multiple vegetation layers, meaning that early changes occurring in the forest floor and understory may be poorly represented in such data.

In this study, we evaluated the potential of Sentinel-1 radar data for monitoring early-spring dynamics in deciduous forests. Satellite radar is sensitive to subtle structural changes within the observed surface, making it a promising tool for detecting early vegetation dynamics. The analysis was conducted in *Betula pendula*-dominated stands located in central Poland, using time series of radar coherence – a measure of the temporal stability of the radar signal. The aim of the study was to assess whether early vegetation changes occurring within the forest ecosystem can be detected in radar observations. The interpretation of satellite data was supported by ground-based phenological observations conducted in 2025, documenting the development of forest floor and understory vegetation as well as the timing of leaf emergence in the tree canopy.

The results indicate that the strongest decreases in radar coherence coincide with periods of rapid spring vegetation development. Early signal variations were associated with vegetation emergence in the lower forest layers, whereas later responses corresponded to leaf development in the tree canopy. These findings suggest that radar observations can support the monitoring of early forest phenology and complement optical data and ground-based observations in studies of forest ecosystem dynamics.