New Unsupervised Bayesian Methodology for Timely Detection of Forest Loss in the Brazilian Amazon and Cerrado Woodland Savanna Using Sentinel-1 Time Series Data

Forests worldwide have undergone significant transformations due to forest loss [7], highlighting the critical need for real-time forest monitoring to prevent further vegetation loss and facilitate prompt interventions. Traditionally, forest loss monitoring relied on optical imagery [3], which is obstructed by its susceptibility to cloud coverage, especially in tropical regions. In recent times, Synthetic Aperture Radar (SAR)-based systems have emerged to enable all-weather operability [2], [5], [6]. However, SAR-based approaches encounter challenges, such as the alterations in backscatter caused by factors like soil moisture variations. Moreover, accurately detecting small-scale disturbances remains problematic for SAR systems, partly due to the spatial filtering techniques employed to mitigate the effects of speckle. Additionally, monitoring forest loss in regions characterized by pronounced seasonality in backscatter signals, such as dry forests and savannas, poses limitations, resulting in substantial under-monitoring of these extensive carbon sinks.

This study introduces an unsupervised SAR-based method for detecting forest loss, employing Bayesian inference through an infinite state Markov chain. The approach treats forest loss as a change-point detection problem within a Radiometrically Terrain Corrected (RTC) Sentinel-1 single polarization time series. Notably, this method preserves the native resolution of measurements without resorting to spatial filtering. Each new observation contributes to the probability of deforestation occurrence, leveraging prior information and a robust data model [1]. The method's sequential adaptation process ensures resilience against variations and trends, facilitating forest loss monitoring not only in dense forests but also in areas influenced by seasonal changes.

In evaluating the proposed method, tests were conducted by comparing different configurations, representing varying levels of conservatism, to existing Near Real-Time (NRT) forest loss monitoring systems, including GLAD-L [3], RADD [6], and combined Global Forest Watch (GFW) alerts during the observation year 2020. In particular, GFW includes alerts from GLAD-L, GLAD-S2, and RADD where available. The assessment focused on small validation polygons (i.e., <1ha) in both the Brazilian Amazon and the Cerrado woodland savanna. The performance metrics such as detections, omissions and false alarms were calculated in comparison to the MapBiomas Alerta validation dataset [4].

Our research unveiled significant progress in detecting small-scale disturbances, accompanied by a remarkable reduction in false alarms across the examined biomes. In the Brazilian Amazon, our method achieved an F1-score of 97.3%, surpassing the 93.1% obtained by the current best-performing NRT system. Furthermore, a focused comparison underscored the existing systems' tendency to overestimate forest loss, likely due to spatial filtering impacting data resolution. In contrast, our method demonstrated more precise detections in absence of filtering and significantly lower false alarm rates in comparison to all considered systems, regardless of the configuration. In the Cerrado, our approach attained an F1-score of 97.4%, distinctly surpassing the 75.5% obtained through leading optical technology. In conclusion, our adaptive approach significantly improved forest loss detection with low false alarm rates, demonstrating efficacy in both the extensively monitored Amazon, and the Cerrado, where seasonal changes pose challenges to existing systems, leading to limitations or the absence of monitoring.

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