New Near Real-Time Deforestation Monitoring Technique Based on Bayesian Inference

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The world's forests have undergone substantial changes in the last decades. In the tropics, 17% of moist forests disappeared between 1990 and 2019, through deforestation and forest degradation [7]. These changes contribute greatly to biodiversity loss through habitat destruction, soil erosion, terrestrial water cycle disturbances, and anthropogenic CO2 emissions. Continuous monitoring of global deforestation is a fundamental tool to support preservation actions and to stop further destruction of vegetation.

Several forest disturbance detection systems have already been developed, mainly based on space-borne optical remote sensing [4] which is severely limited by cloud coverage in the tropics. Contrarily to optical imagery, SAR products have the great potential of being insensitive to the presence of clouds. In recent years, several SAR-based systems have been developed and are now operational in different dense forest areas across the tropics [2], [3], [5], [6]. Despite the extensive coverage and temporal density of acquisitions, C-band SAR data like Sentinel-1 are not ideal for deforestation monitoring since the returned backscatter can be altered by variations in soil moisture and others.

In this work, we investigate a new method to monitor forest loss in a near real-time manner exploiting the principle of Bayesian inference. In particular, forest loss is treated as a change-point detection problem within a univariate time series (i.e. Sentinel-1 single polarization), in which each new observation contributes to the probability of having or not deforestation in a Bayesian-like manner [1]. Detection delay and false alarm reduction have been investigated through the extension of the algorithm to the multivariate case of dual-polarization Sentinel-1 acquisitions. Given the synchronous nature of VV, VH acquisitions, such a modification allows an increase in the equivalent number of looks on a pixel on the ground, hence augmenting the level of confidence of an issued alert.

A validation campaign has been conducted to assess the performance of the method. The test sites are located in French Guiana and Brazil where deforestation takes place constantly and near real-time monitoring is fundamental for law enforcement practices. Additionally, a comparison with a well-known deforestation monitoring technique, namely Maximum Likelihood Ratio Test, has been performed to further evaluate the proposed method. Conclusively, the potential of extending the current method to asynchronous data sources such as Sentinel-2 optical data is addressed.

References

[1] Adams and MacKay. Bayesian Online Changepoint Detection. 2007. arXiv: 0710.3742 [stat.ML].

[2] Bouvet et al. "Use of the SAR Shadowing Effect for Deforestation Detection with Sentinel-1 Time Series". In: Remote Sensing (2018).

[3] Doblas et al. "DETER-R: An Operational Near-Real Time Tropical Forest Disturbance Warning System Based on Sentinel-1 Time Series Analysis". In: Remote Sensing (2022).

[4] Hansen et al. "Humid tropical forest disturbance alerts using Landsat data". In: Environmental Research Letters (2016).

[5] Mermoz et al. "Continuous Detection of Forest Loss in Vietnam, Laos, and Cambodia Using Sentinel-1 Data". In: Remote Sensing (2021).

[6] Reiche et al. “Forest disturbance alerts for the Congo Basin using Sentinel-1”. In: Environmental Research Letters (2021).

[7] Vancutsem et al. “Long-term (1990–2019) monitoring of forest cover changes in the humid tropics”. In: Science Advances 7 (2021)