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Outstanding Student & PhD candidate Presentation contest

Advanced Backscatter Modeling for Enhanced Detection of Forest Disturbances in the Indian Subcontinent

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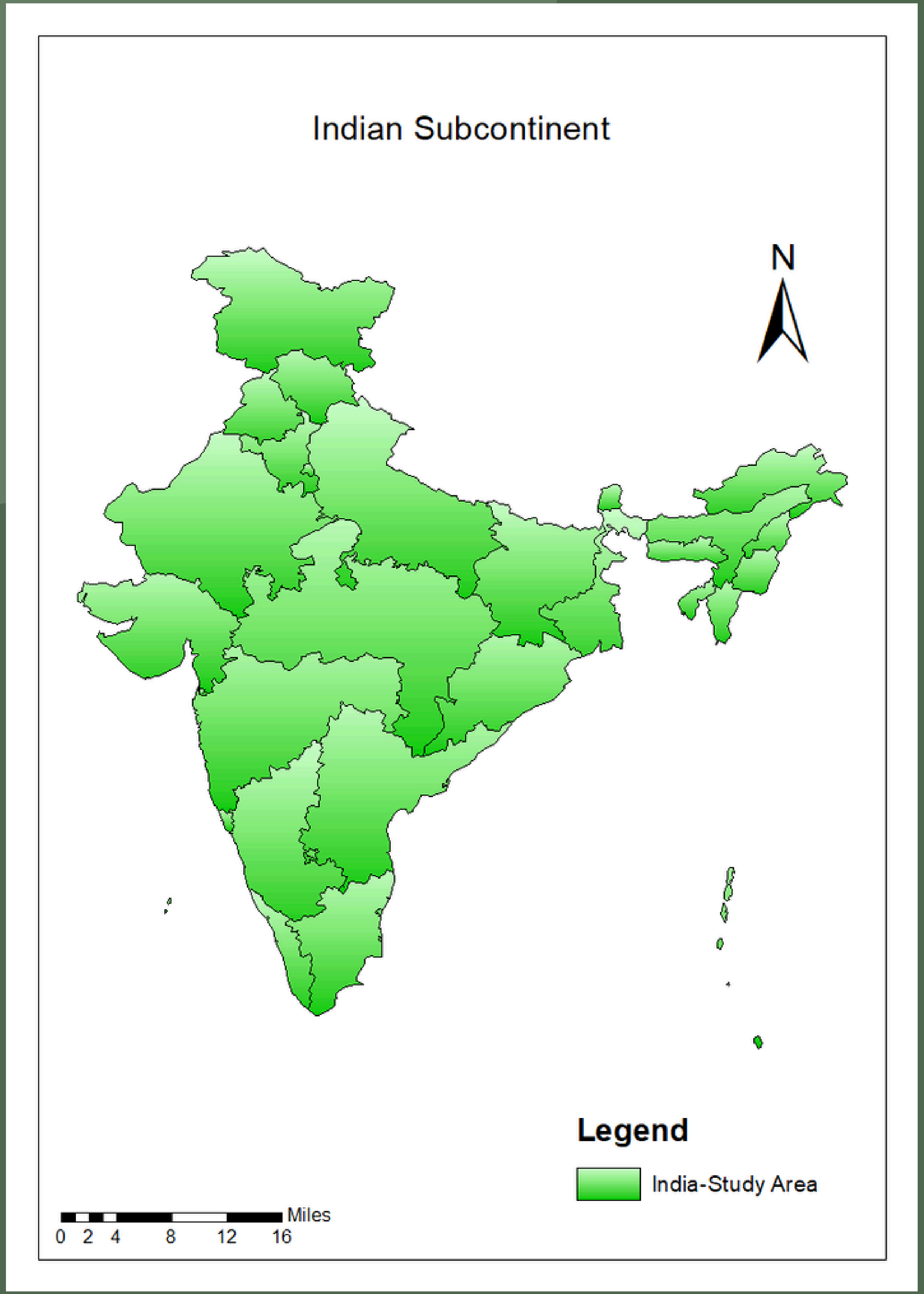
Introduction

- Forests in the Indian subcontinent are vital ecosystems, supporting biodiversity and essential ecological services.
- Synthetic Aperture Radar (SAR) data, especially backscatter, is effective for monitoring changes due to its cloud-penetrating and vegetation-sensitive properties.
- Traditional backscatter analysis struggles to detect subtle forest changes in complex terrain and mixed vegetation types.
- This study investigates advanced backscatter modeling techniques to better detect and characterize forest disturbances.
- Techniques used include:
- Temporal filtering
- Polarization decomposition
- Machine learning-based classification



Objectives

1. To develop and apply an advanced backscatter modeling framework using multi-temporal Sentinel-1 SAR data for detecting and mapping forest disturbances across diverse ecological zones of the Indian subcontinent, incorporating the Coherence Stability Index (CSI) to assess structural forest changes over time.
2. To evaluate forest degradation intensity through the integration of the Radar Forest Degradation Index (RFDI) with polarization-based backscatter metrics, aiming to improve the sensitivity and reliability of disturbance detection in heterogeneous forest landscapes.

Methodology

- Source: Use Sentinel-1 SAR multi-temporal data (VV and VH polarizations) over the Western Ghats.
- Preprocessing: Apply radiometric calibration, terrain correction, and speckle filtering.
- Time-Series Stack: Create time-series backscatter stacks to capture forest dynamics.
- Index Computation:

Compute Coherence Stability Index (CSI) for temporal coherence changes.

Derive Radar Forest Degradation Index (RFDI) from VH and VV backscatter.

Additional Features: Extract SAR metrics like backscatter ratio and texture features.

- Classification:

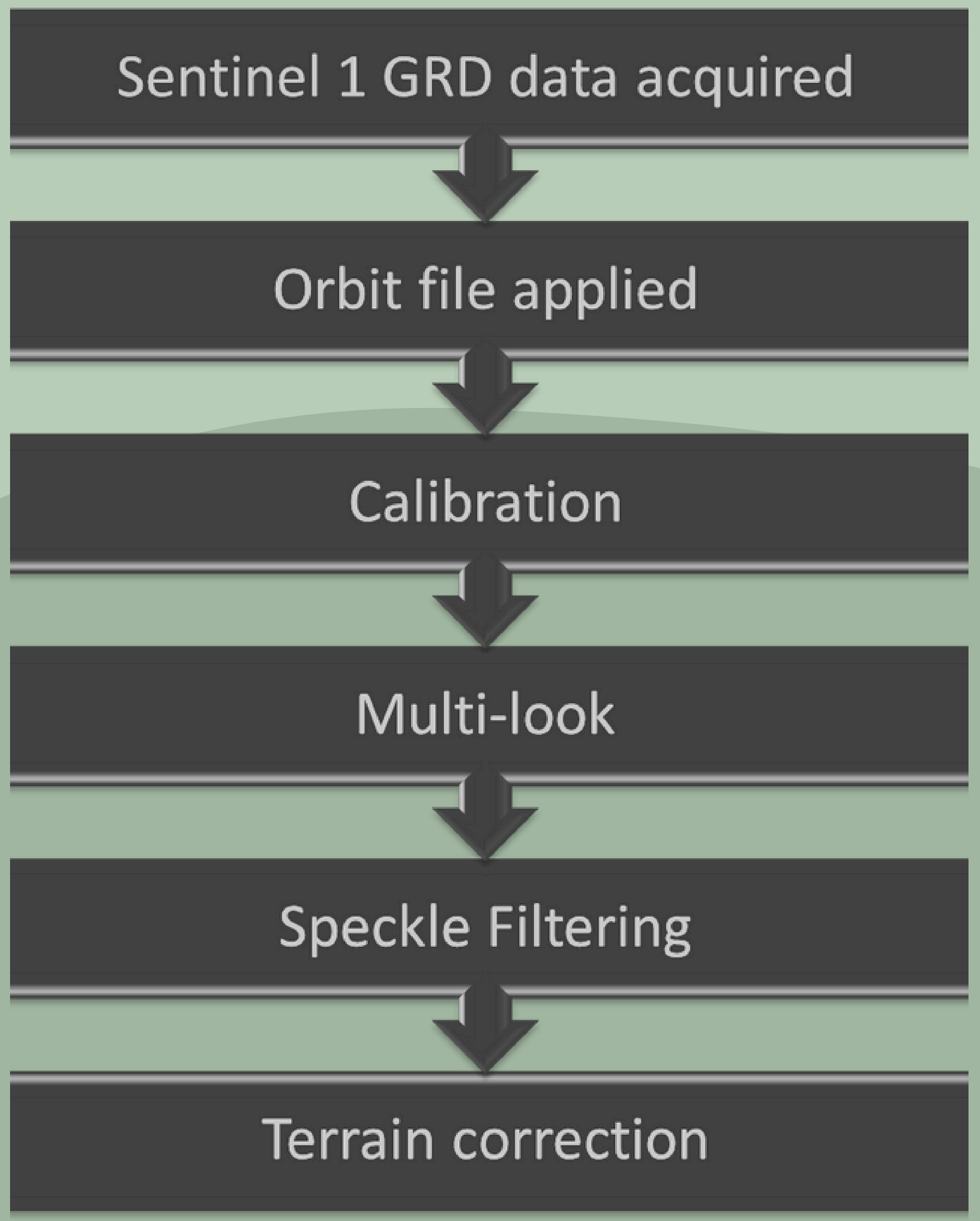
Use a supervised machine learning model (Random Forest) to classify disturbed vs. undisturbed forests.

Train and validate using ground truth data and high-resolution Sentinel-2 imagery.

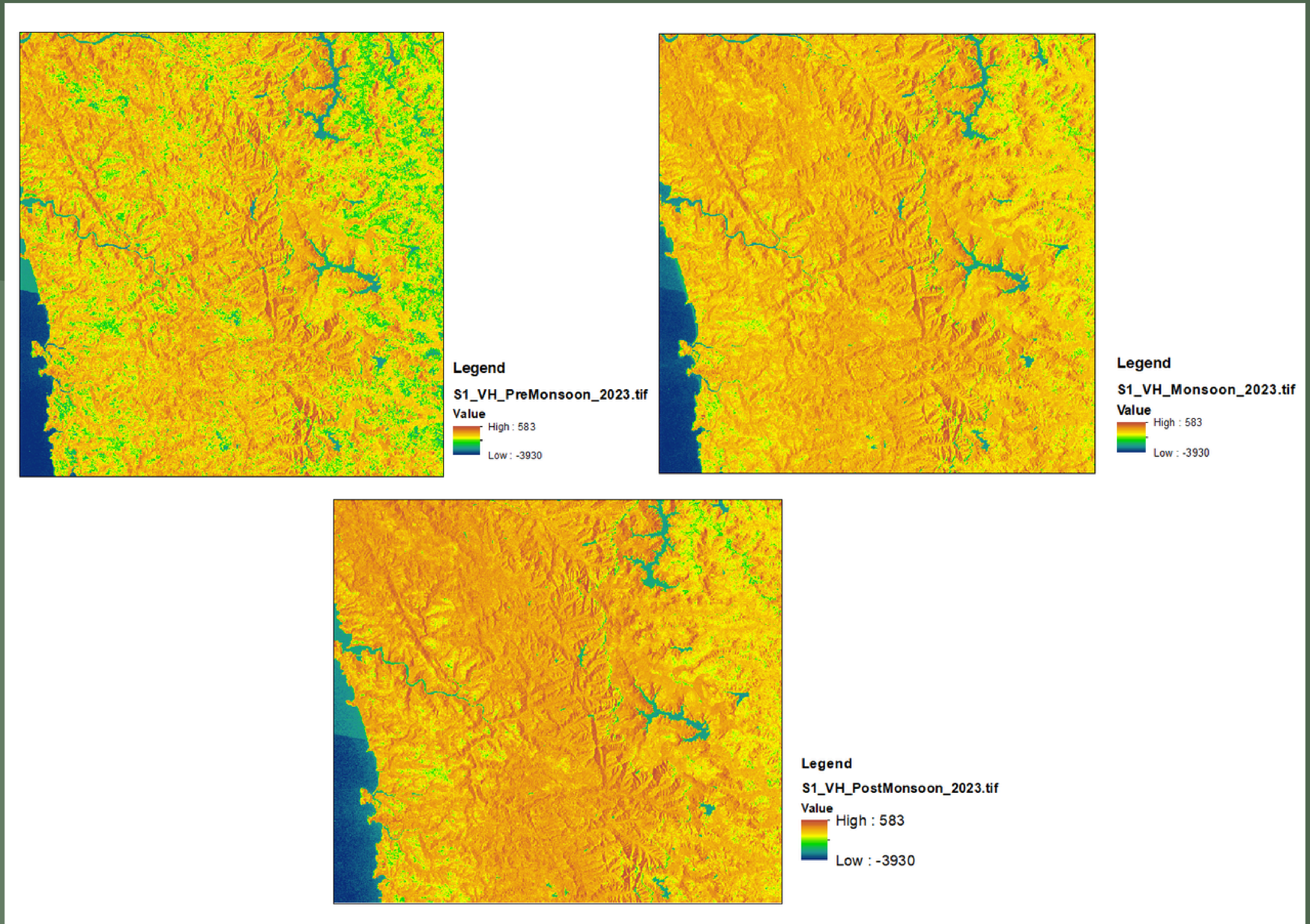
- Evaluation:

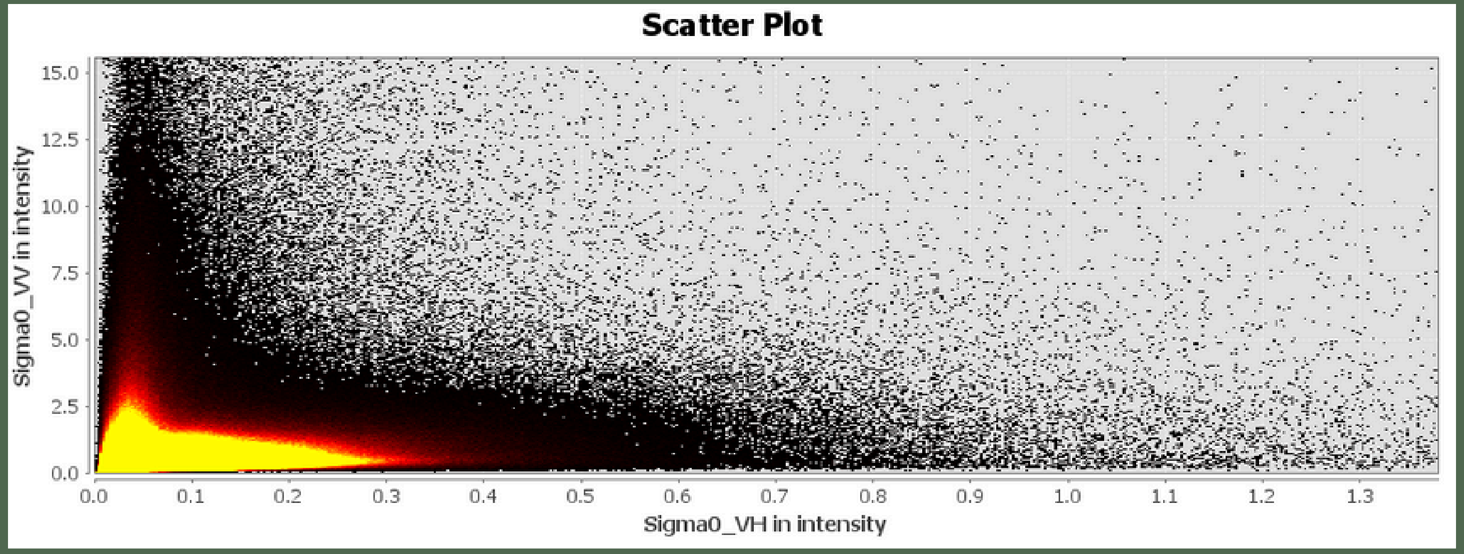
Assess model accuracy with standard metrics.

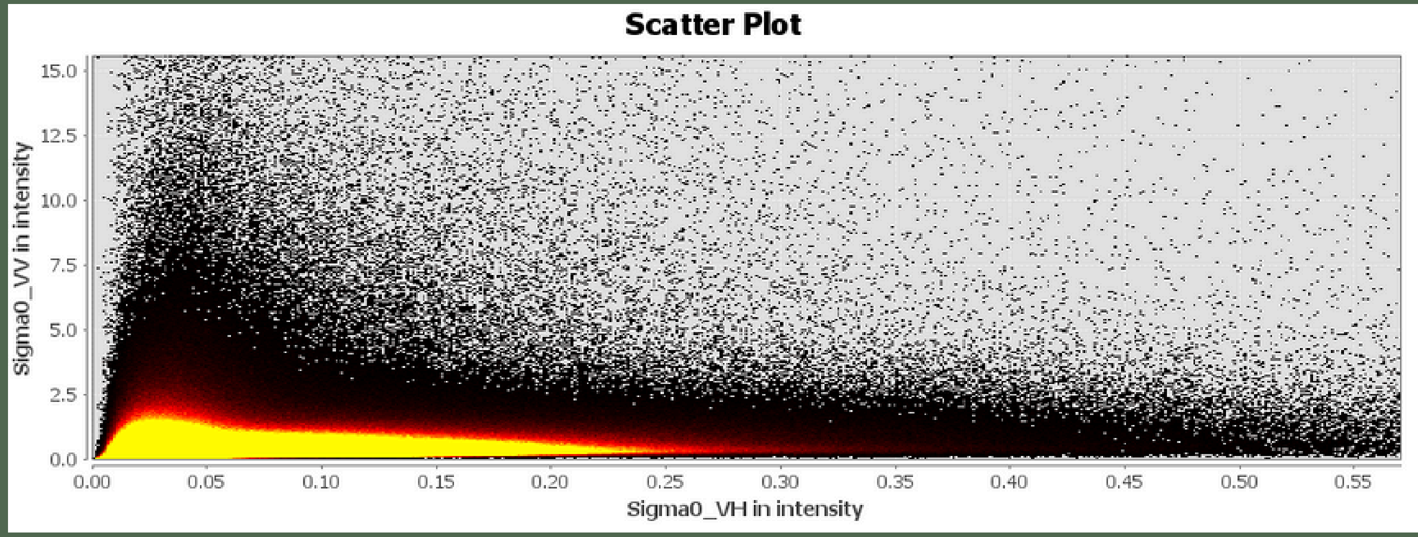
Validate spatially with known disturbance events.



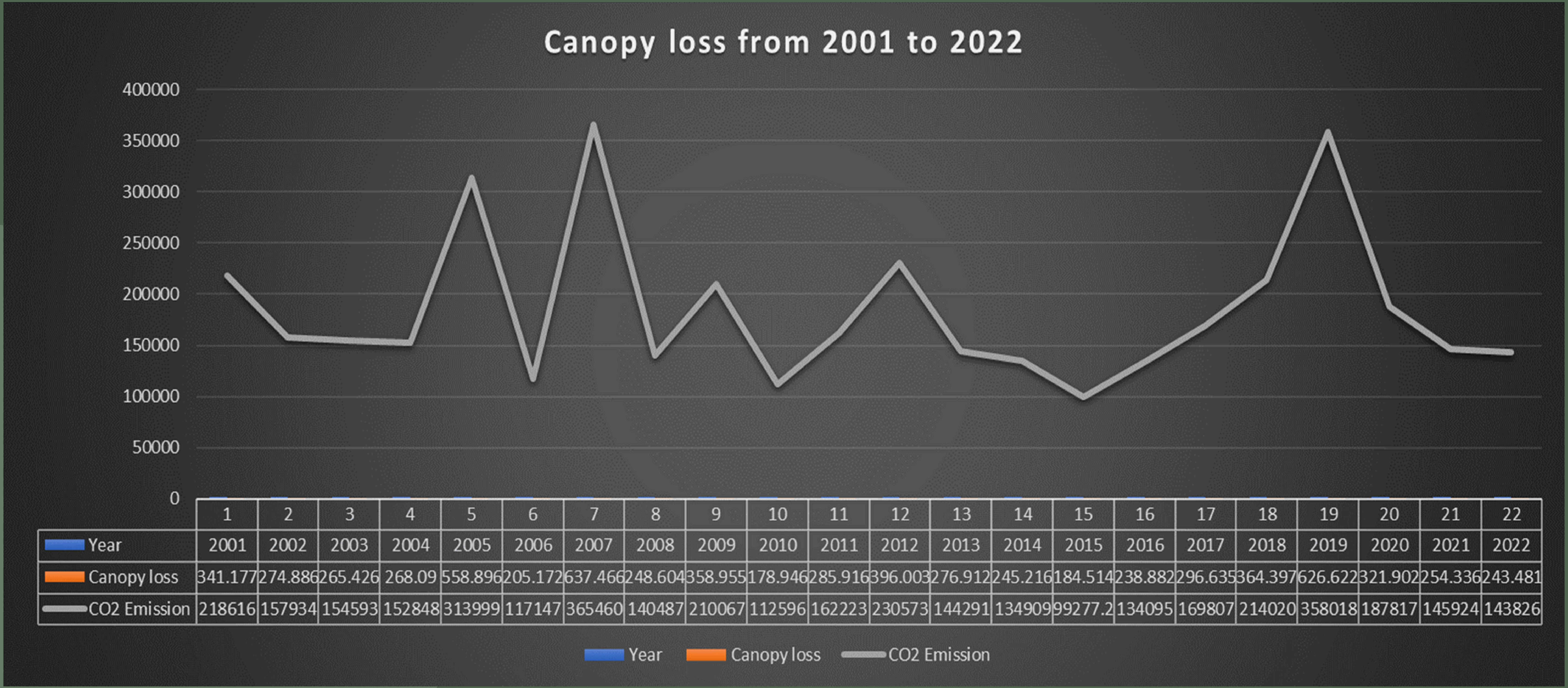
Analysis


Legend
S1_VH_PreMonsoon_2023.tif
Value
High : 583
Low : -3930
Legend
S1_VH_Monsoon_2023.tif
Value
High : 583
Low : -3930
Legend
S1_VH_PostMonsoon_2023.tif
Value
High : 583
Low : -3930


Scatter Plot
Sigma0_VV in intensity
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3
Sigma0_VH in intensity


Scatter Plot
Sigma0_VV in intensity
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55
Sigma0_VH in intensity

Analysis



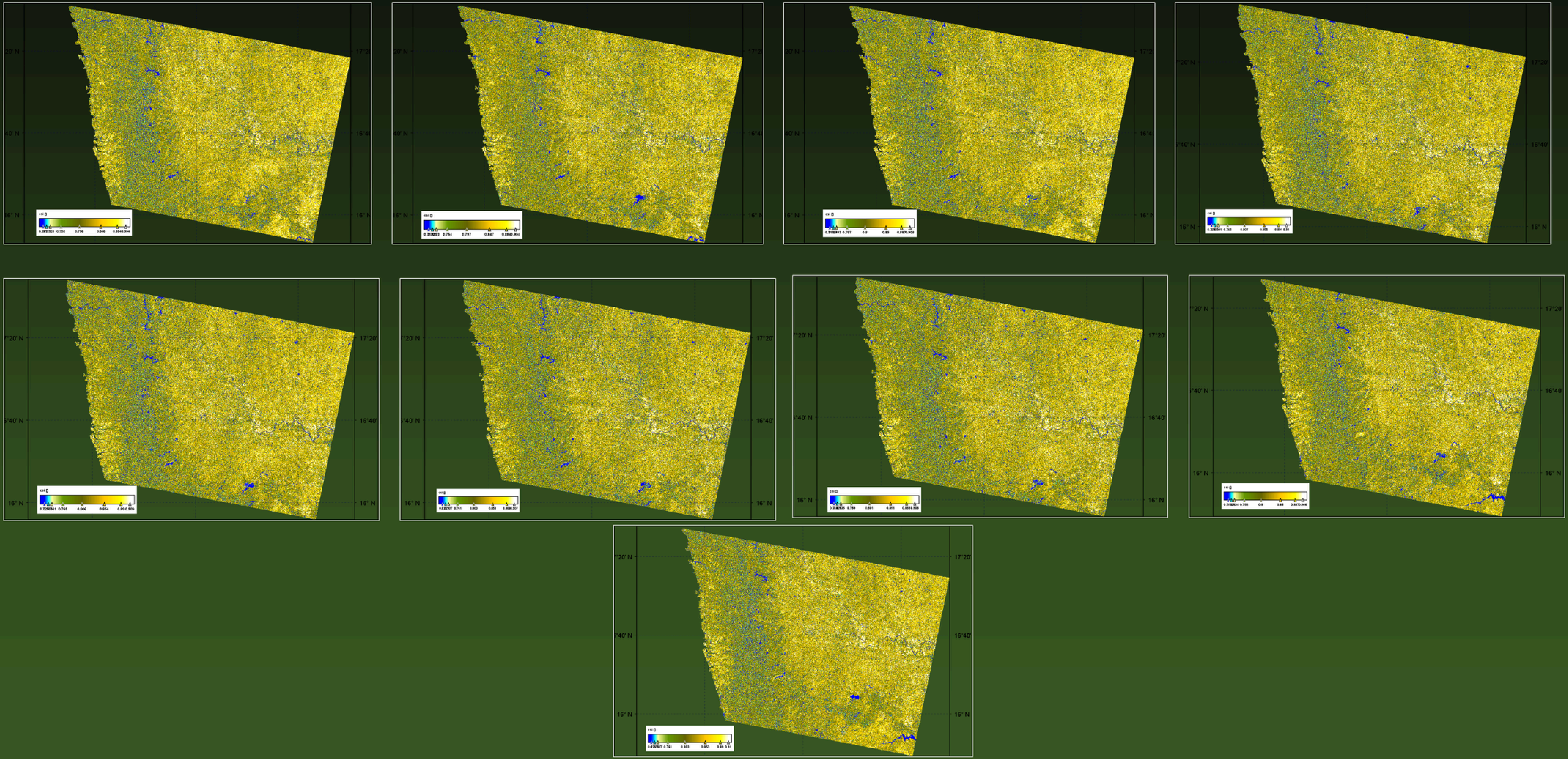
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Canopy loss	341.177	274.886	265.426	268.09	558.896	205.172	637.466	248.604	358.955	178.946	285.916	396.003	276.912	245.216	184.514	238.882	296.635	364.397	626.622	321.902	254.336	243.481
CO2 Emission	218616	157934	154593	152848	313999	117147	365460	140487	210067	112596	162223	230573	144291	134909	99277.2	134095	169807	214020	358018	187817	145924	143826

Canopy Structure Index (CSI)

- Optical remote sensing-derived metric integrated in radar.
- High CSI: Dense, undisturbed forests.
- Low CSI: Sparse, degraded canopies.

$$CSI = \frac{(VH+VV)}{(VH-VV)}$$

CSI (PRE-DISTURBANCE, 2017-2023)



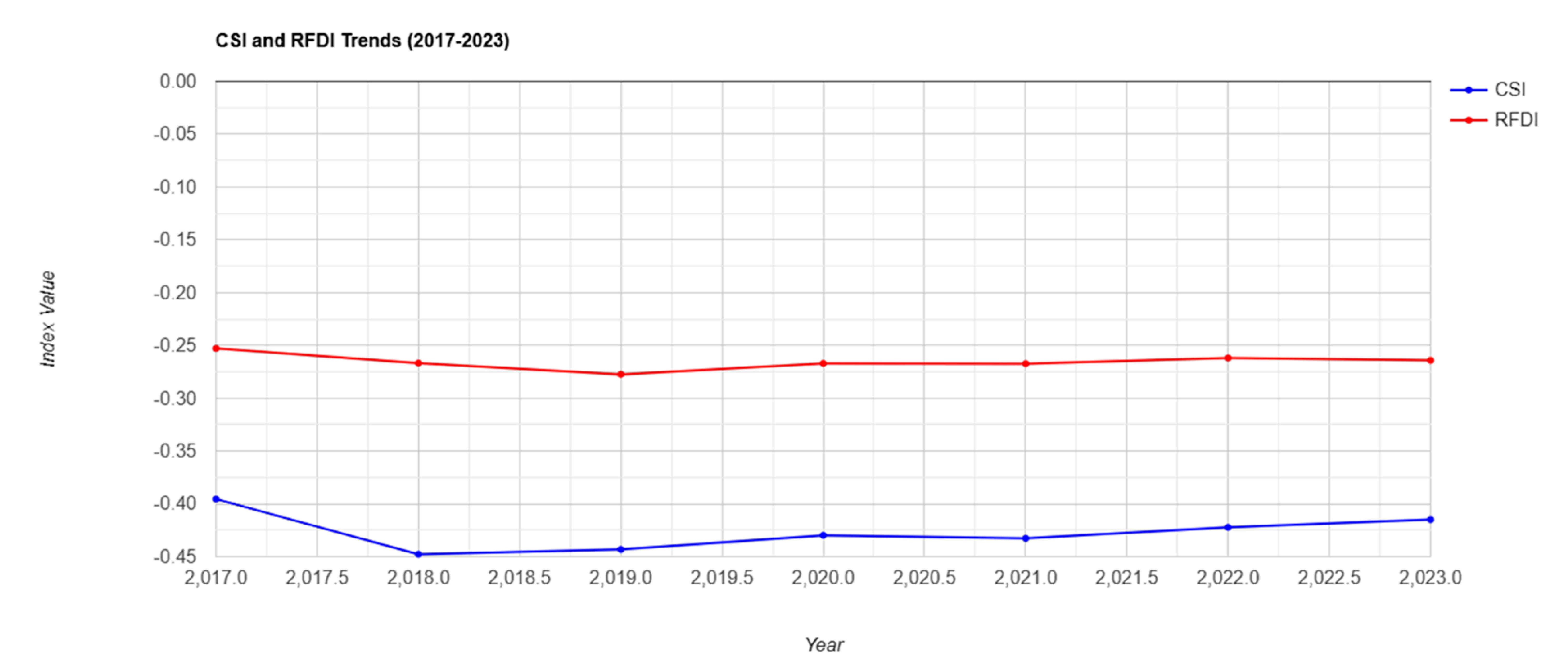
CSI (POST-DISTURBANCE, 2017-2023)

Radar Forest Degradation Index (RFDI)

- Derived from Synthetic Aperture Radar (SAR) data.
- High RFDI: Significant degradation.
- Low RFDI: Stable forest structures.

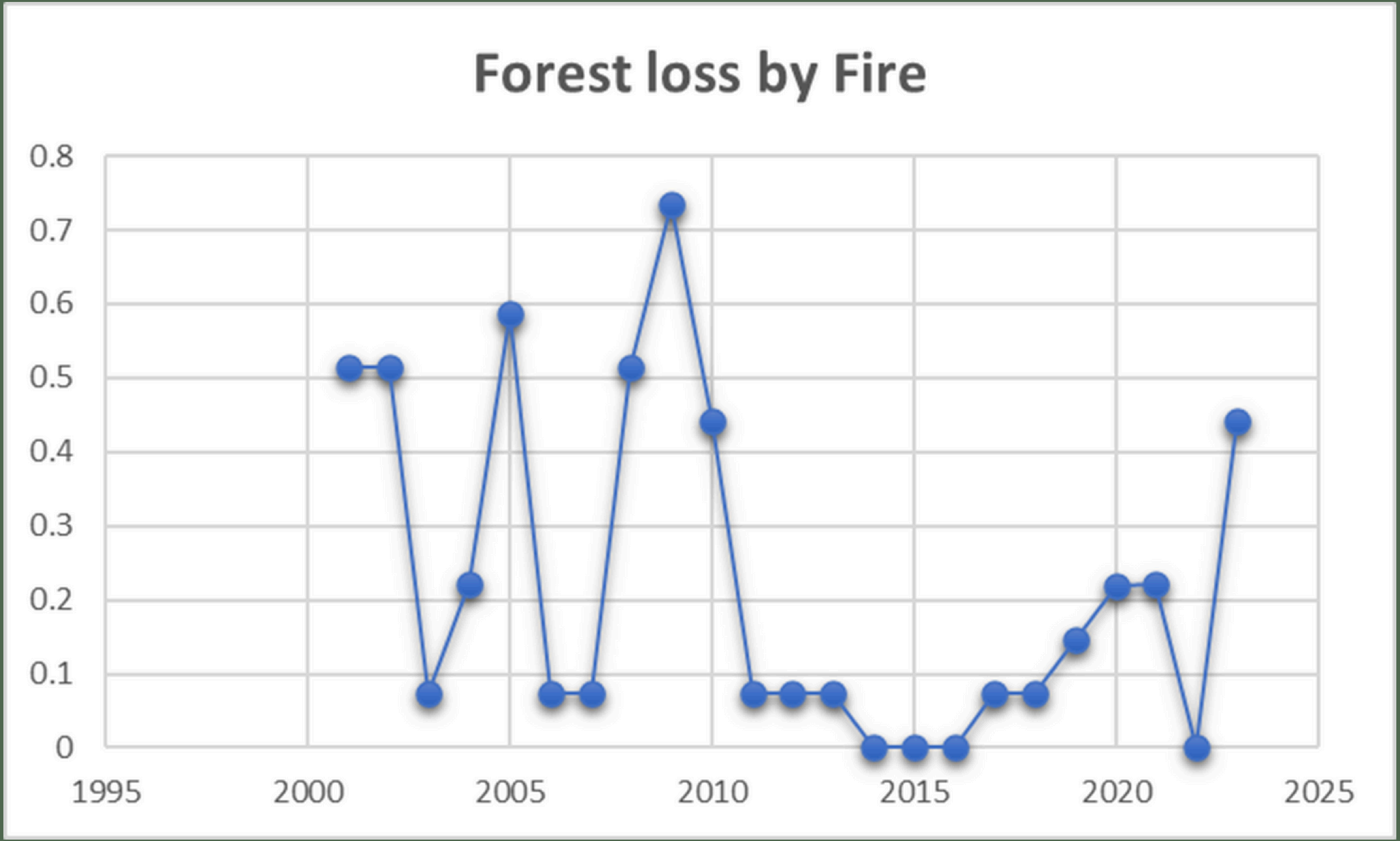
$$RFDI = \frac{VH + VV}{(VH - VV)} \times \left(\frac{1}{Backscatter\ Intensity} \right)$$

Results



CSI and RFDI Trends (2017-2023)
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
-0.40
-0.45
Index Value
2,017.0
2,017.5
2,018.0
2,018.5
2,019.0
2,019.5
2,020.0
2,020.5
2,021.0
2,021.5
2,022.0
2,022.5
2,023.0
Year
CSI
RFDI

Results



Forest loss by Fire
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1995
2000
2005
2010
2015
2020
2025

High risk zones