Sanjana Dutt

Forest Fragmentation Dynamics in Tuchola Forest, Poland. A Multiscale Analysis Using Remote Sensing

Abstract

Forest fragmentation significantly affects biodiversity, carbon sequestration, and ecosystem resilience. Yet temperate forests—such as those in northern Poland within the Tuchola Forest Biosphere Reserve (TFBR; Polish: RBBT)—remain understudied compared with tropical systems. This dissertation analyzes fragmentation dynamics in the TFBR, a landscape shaped by monocultural forest management, strong land-use pressure, and extreme events, notably the August 2017 windstorm. Using satellite remote sensing at multiple resolutions (Sentinel-2, ALOS PALSAR, Landsat-8, CORINE), advanced landscape metrics (e.g., Forest Area Density, FAD), and machine-learning methods, I examine multiscale and multitemporal patterns, ecological consequences, and monitoring strategies to support adaptive protection and increase resilience.

The thesis addresses four questions: (i) How have methods for assessing forest fragmentation evolved? (ii) How do fragmentation and multiscale disturbances alter forest structure and landscape coherence? (iii) Which ecological processes dominate across fragmentation zones (core, transition, sparse)? (iv) Which vegetation indicators best support monitoring, prioritization, and conservation effectiveness? Across five articles, the dissertation: traces a methodological shift from patch-based metrics to connectivity-oriented approaches (Article 1); establishes reference conditions for pre-disturbance baselines and the onset of fragmentation assessment (Article 2); quantifies post-2017 loss of core forest and expansion of edge zones (Article 3); maps susceptibility to hurricane-force winds using a proprietary fragmentation-risk framework that highlights interfaces with agricultural land (Article 4); and identifies water stress and related processes using Sentinel-2 indices and machine learning (Article 5).

This work provides a scalable, open analytical framework that integrates remote sensing, landscape metrics, and machine learning to assess structural and functional fragmentation, with applications to core-area protection and corridor restoration. Limitations include the lack of LiDAR for 3-D validation, dependence on detailed inventory data, and computational constraints for large-scale modeling. Future research should incorporate voxel-based metrics, deep learning, and continuous validation with high-quality field data.

The methodology is transferable beyond the Tuchola Forest Biosphere Reserve to temperate and boreal forests using cloud platforms (e.g., Google Earth Engine). It supports the Kunming–Montreal Global Biodiversity Framework (30×30 by 2030) and REDD+ MRV objectives, and advances SDGs 15 (Life on Land), 13 (Climate Action), and 6 (Clean Water and Sanitation) by providing practical elements for biodiversity conservation and climate adaptation in temperate forests.

Keywords: Forest fragmentation, landscape metrics, connectivity, remote sensing, machine learning, Tuchola Forest, TFBR, temperate forests, conservation planning, Kunming–Montreal Framework, REDD+ MRV.