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Forest resilience evaluation and management at stand level using remote sensing technologies

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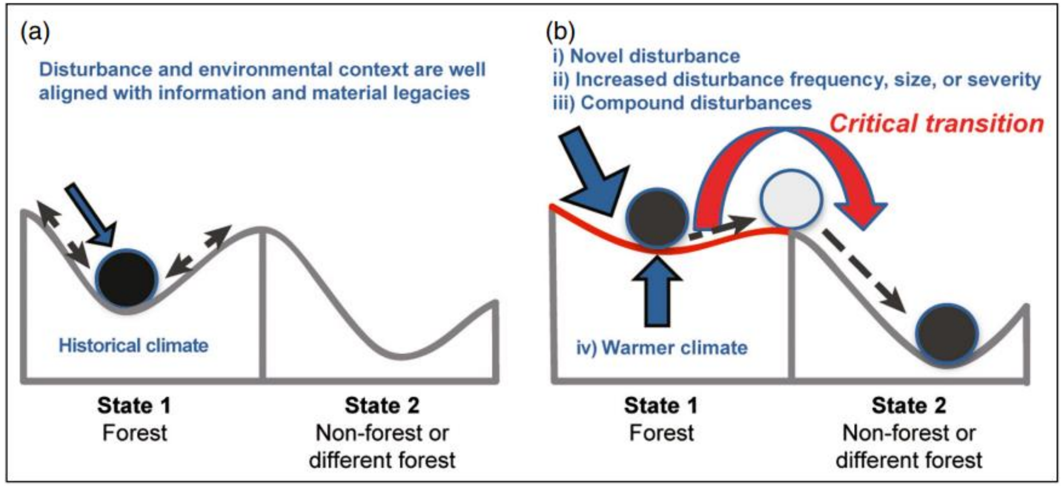
Outline

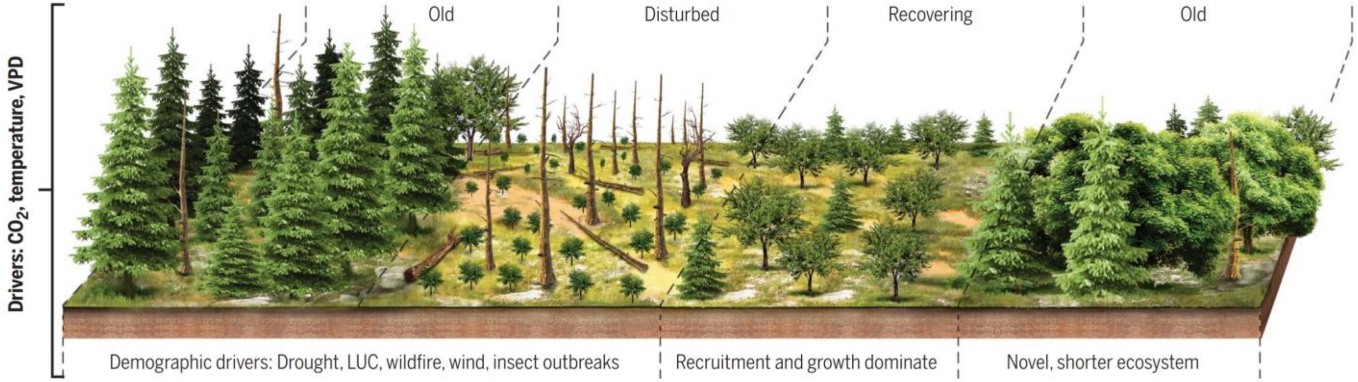
- **Overview**
- **Time-series satellite remote sensing data for forest disturbances detection**
- **Airborne remote sensing for stand level parameter estimation towards management treatment**
- **Summary**

Overview

- Forest resilience refers to the ability of a forest ecosystem to withstand and recover from disturbances (Scheffer et al., 2009; Falk et al., 2022).
- Resilience in forests involves various ecological processes and dynamics that enable the ecosystem to adapt, regenerate, and maintain its integrity over time (Falk et al., 2022).
- Forest resilience is crucial for the sustainability and persistence of forest ecosystems in the face of changing environmental conditions and disturbances.



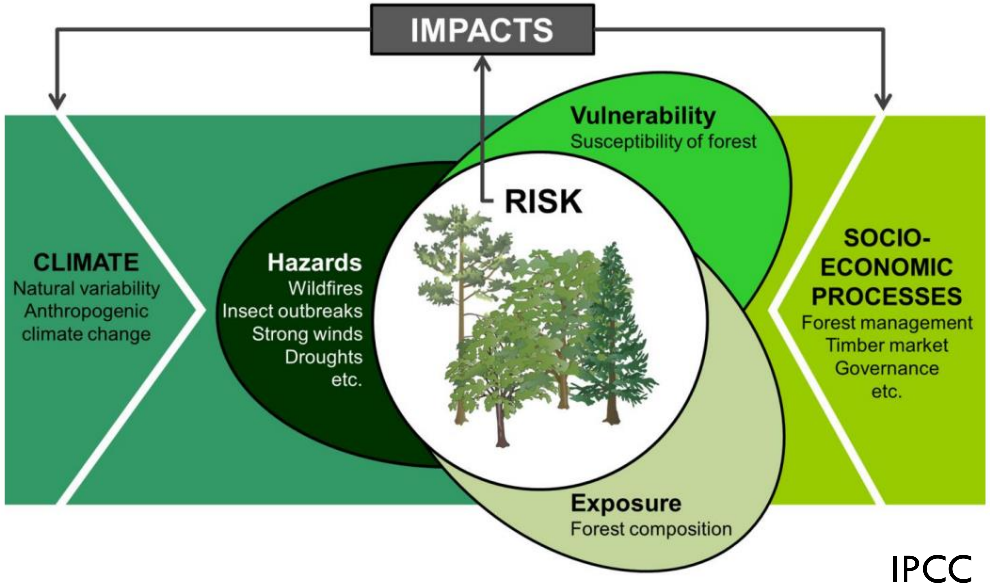
Johnstone et al.. Frontiers in Ecology and the Environment, 2016.



McDowell et al. Science, 2020.

Overview

- The enhancement of forest ecosystem resilience is a global trend in forestry development (Mina et al., 2022).
- Forest resilience evaluation at stand level could provide some information for forest management measures.
- Remote sensing technologies, such as LiDAR, hyperspectral remote sensing, provide good solutions for forest resilience evaluation at stand level.



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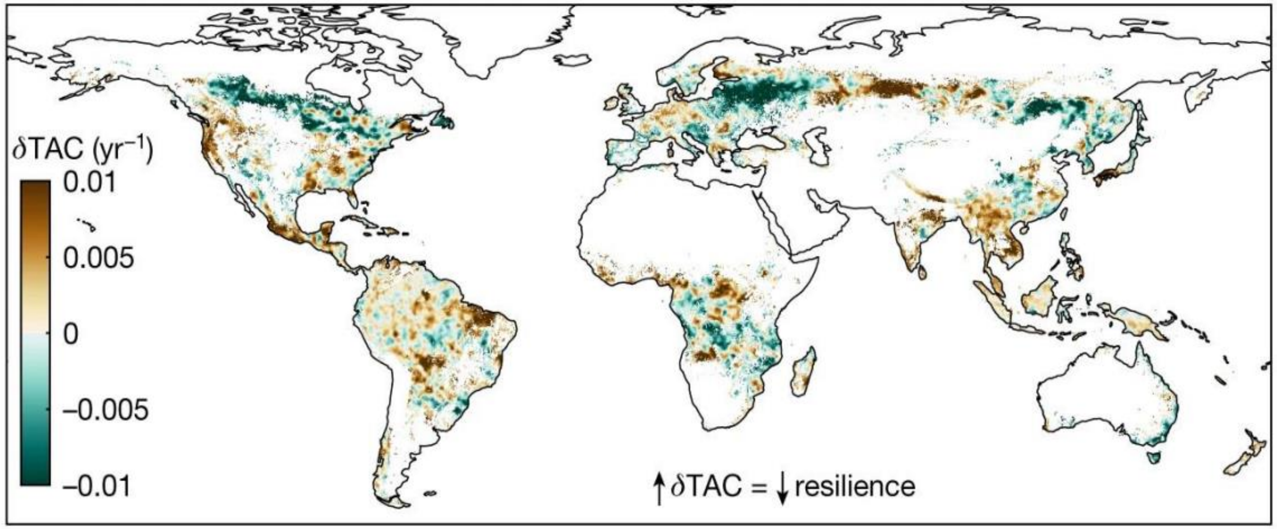
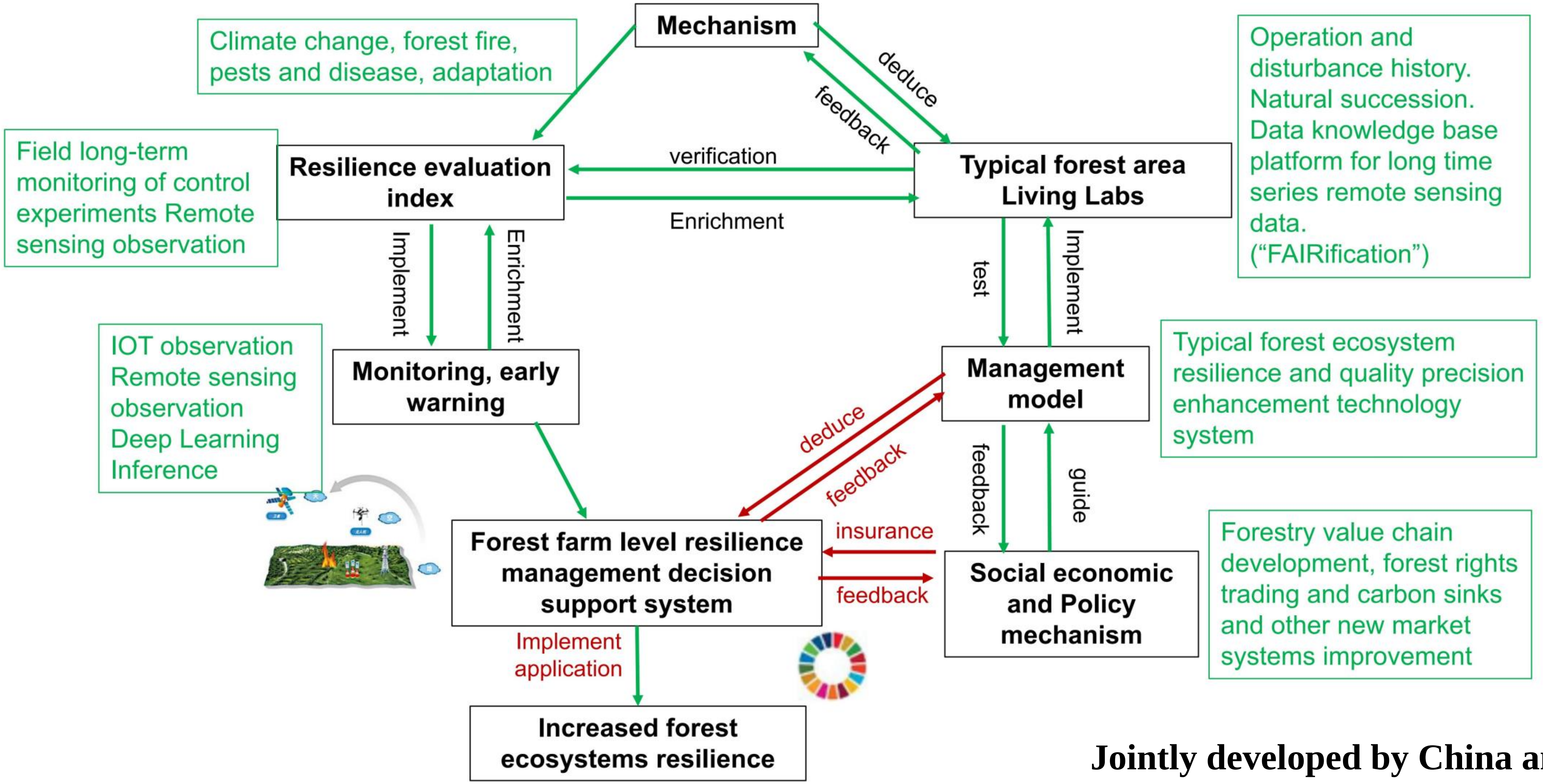


Forzieri et al., Nature,2022

Eco2Adapt-China

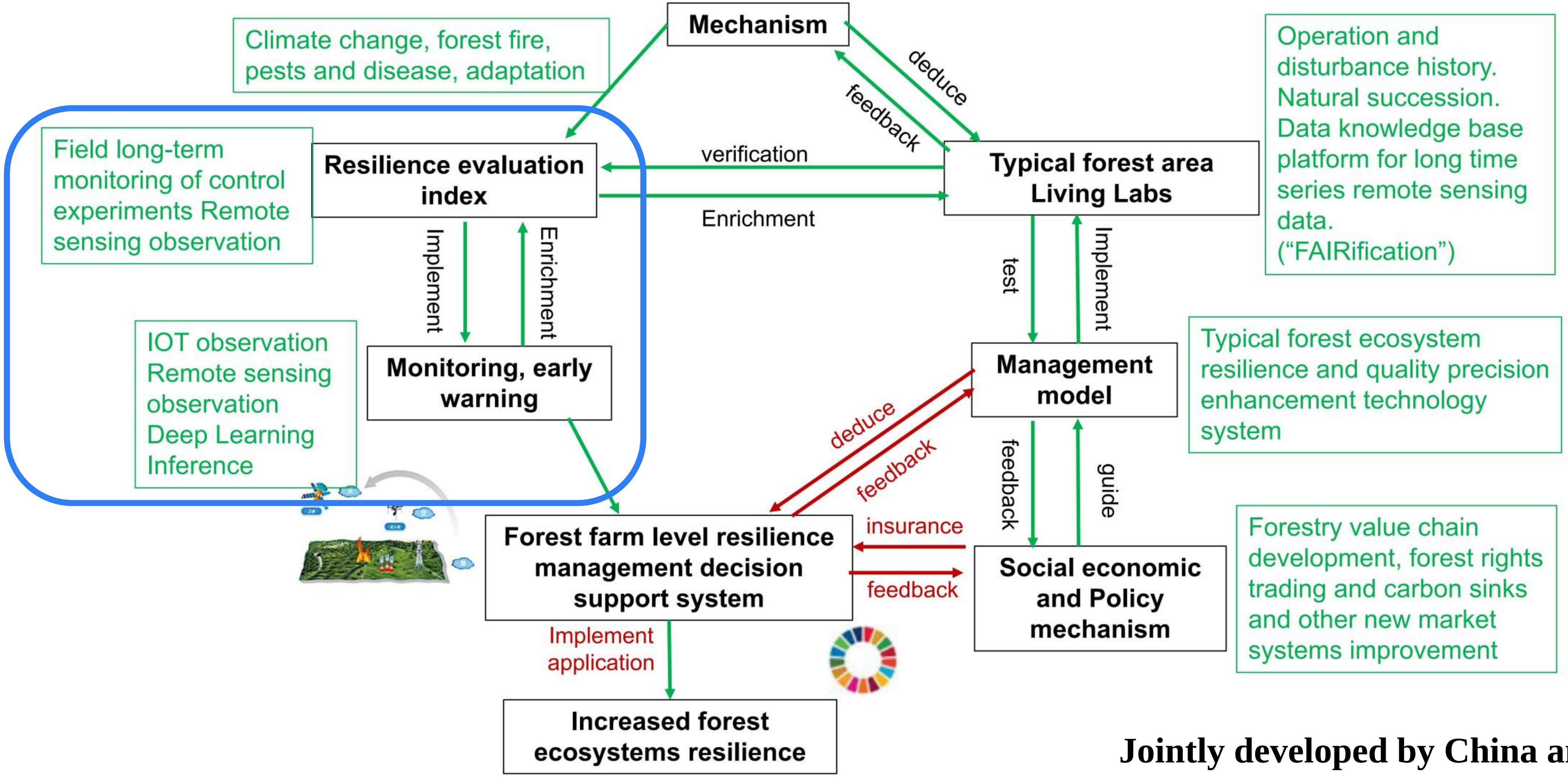
- Eco2Adapt-China duration: Oct. 2023 - Sep. 2026.



Jointly developed by China and Europe

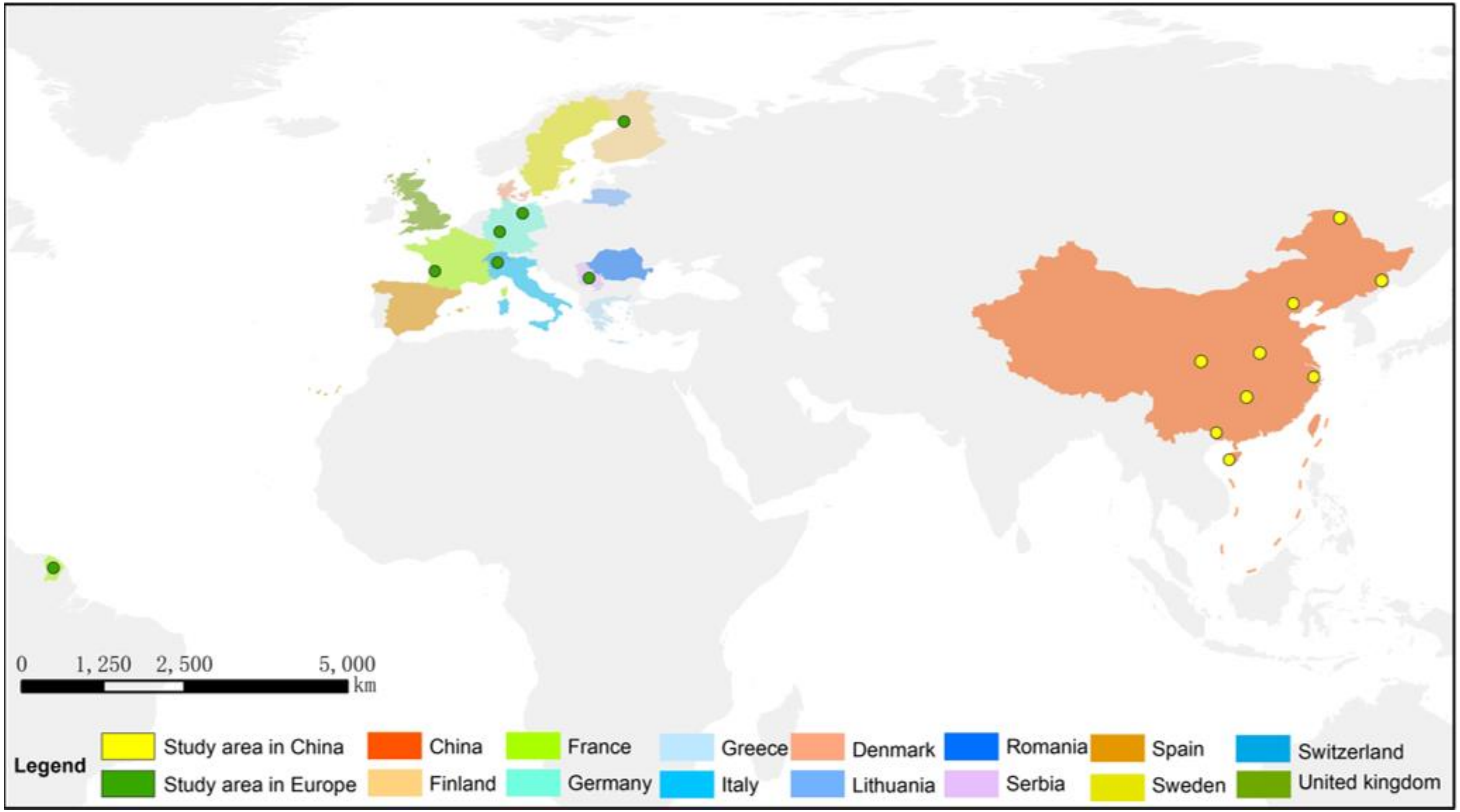
Eco2Adapt-China

- Eco2Adapt-China duration: Oct. 2023 - Sep. 2026.
- Budget ￥15 mio.



Jointly developed by China and Europe

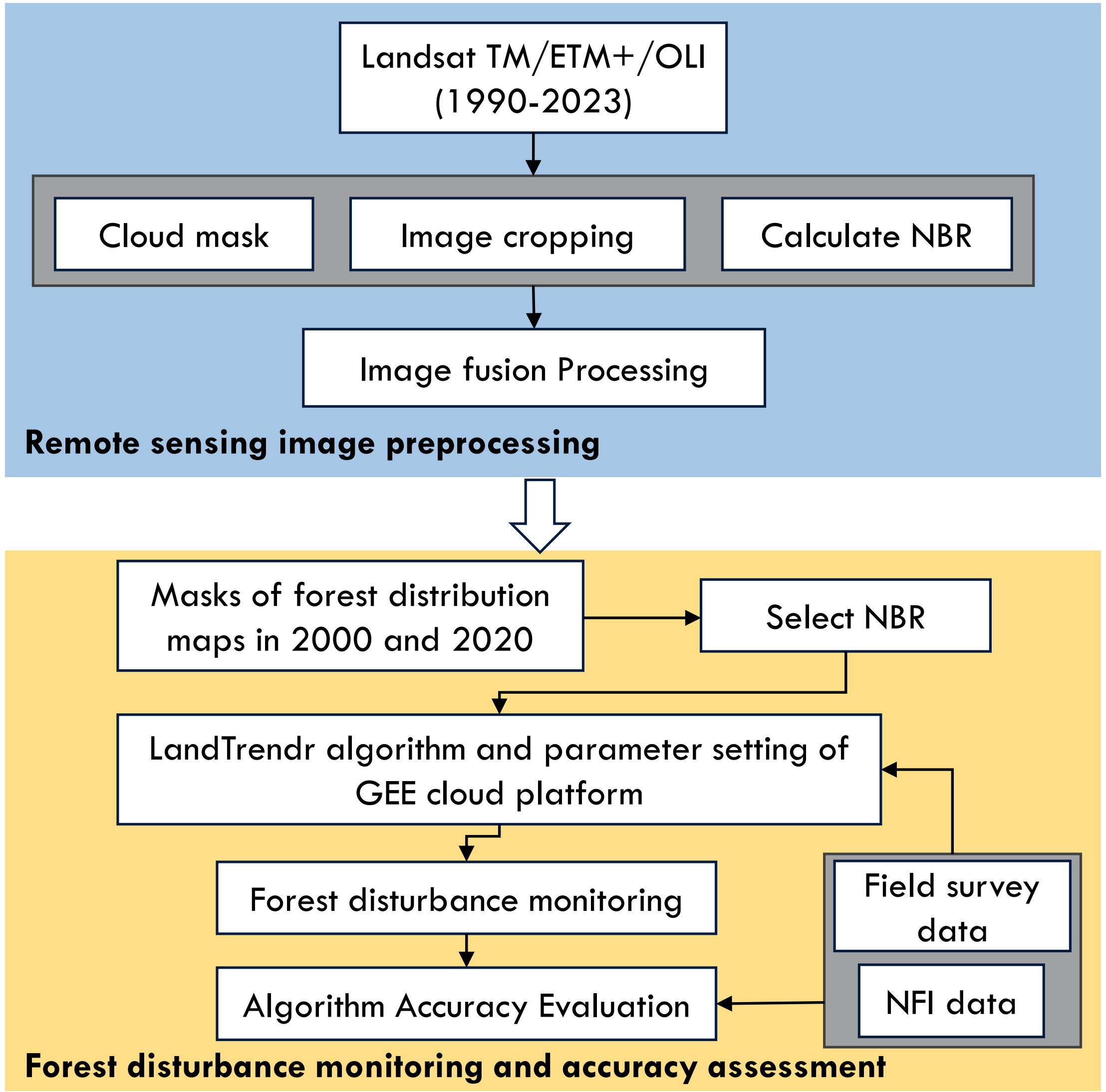
Study area



Distribution of study areas in China and Europe

Time-series satellite remote sensing data for monitoring forest disturbances

- Preprocesses Landsat 5/7/8 images from 1990 to 2023. The Normalized Burn Ratio (NBR) index is selected for forest disturbance monitoring, and the green leaf season in Hainan is defined as April 15th to November 30th each year.
- This study extracts the forest pixels of the land cover product CAF-LC30 in 2000 and 2020, and uses them as a forest background map mask to remove non-forest pixels (Meng et al. 2022). Combined with the LandTrendr time series segmentation results of ground sample points, the parameters of the algorithm are optimized and the forest disturbance monitoring results are obtained.
- Combining field survey data, the accuracy is evaluated by viewing Google historical images and combining it with LandTrendr fitting curves.



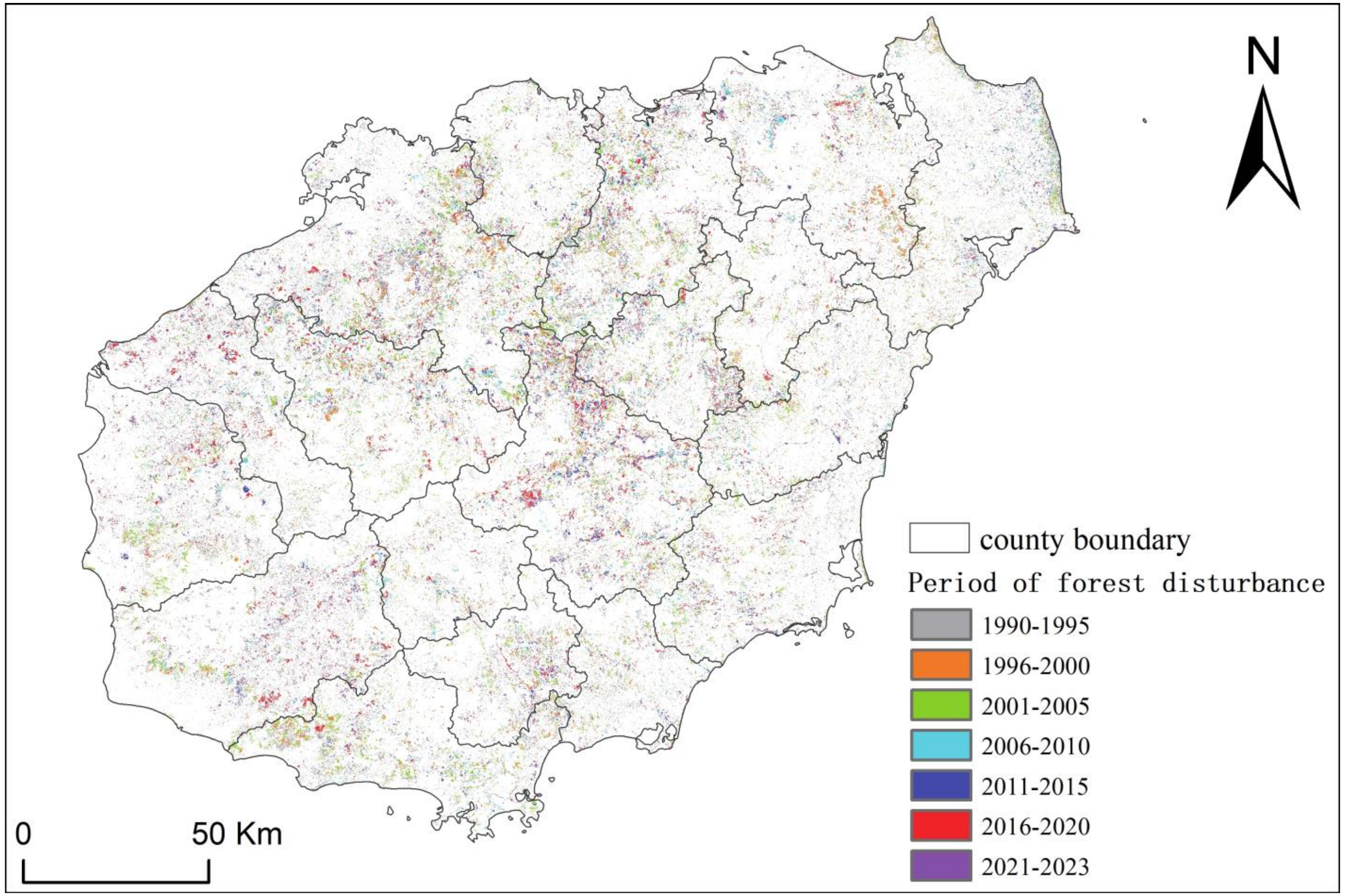
Meng, Shili, Yong Pang, Chengquan Huang, and Zengyuan Li. 2022. Improved forest cover mapping by harmonizing multiple land cover products over China, GIScience & Remote Sensing, 59: 1570-97.

Time-series satellite remote sensing data for monitoring forest disturbances

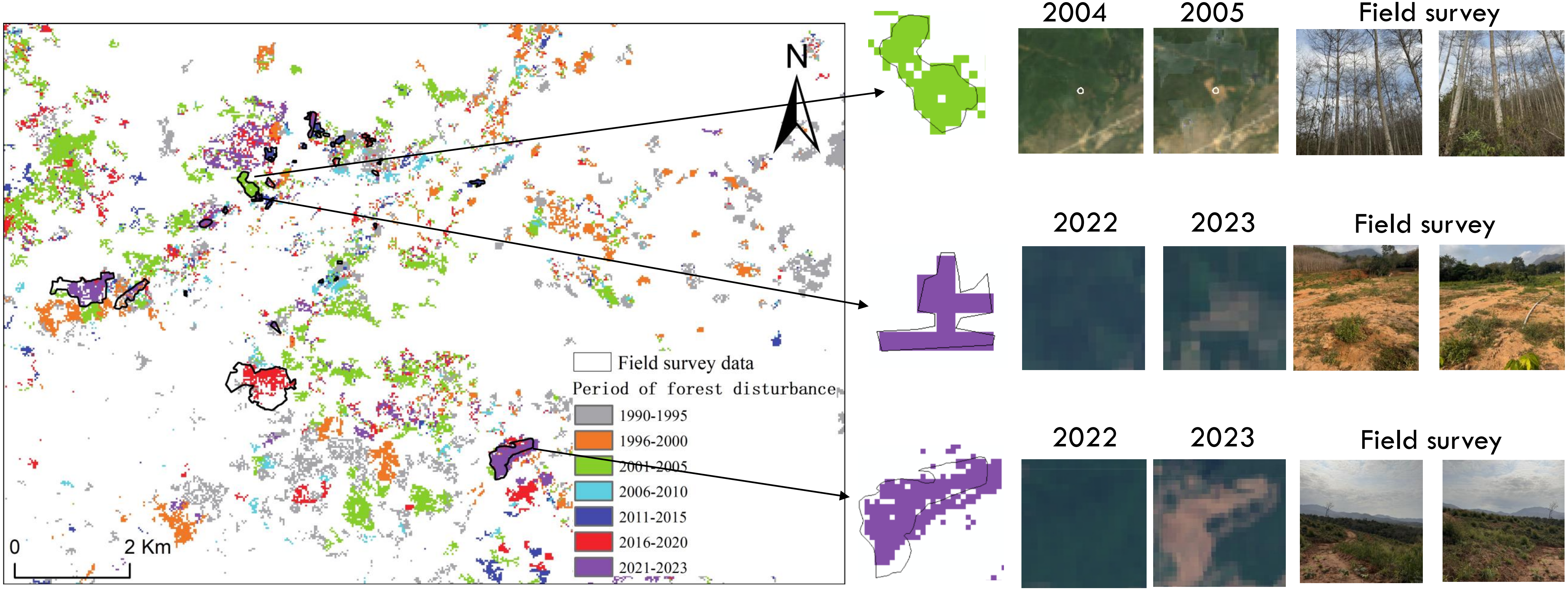
- Algorithm parameter setting

Parameters	Description	Value
maxSegments	The maximum number of segments fitted over a time series	8
spikeThreshold	Threshold for inhibition spikes (1.0 means no inhibition)	0.9
vertexCountOvershoot	The number of vertices that the initial model can exceed	3
preventOneYearRecovery	Prevents recovery events that complete with only 1a	false
recoveryThreshold	If a section's recovery speed exceeds the 1/ recovery threshold, the section is not allowed	0.50
pvalThreshold	If the P-value of the fitted model exceeds this threshold, the current model is abandoned	0.05
bestModelProportion	The minimum vertex value selected by the model	0.75
minObservationsNeeded	Minimum observation required for output fitting	5

Forest disturbance monitoring mapping in Hainan Island(1990-2023)

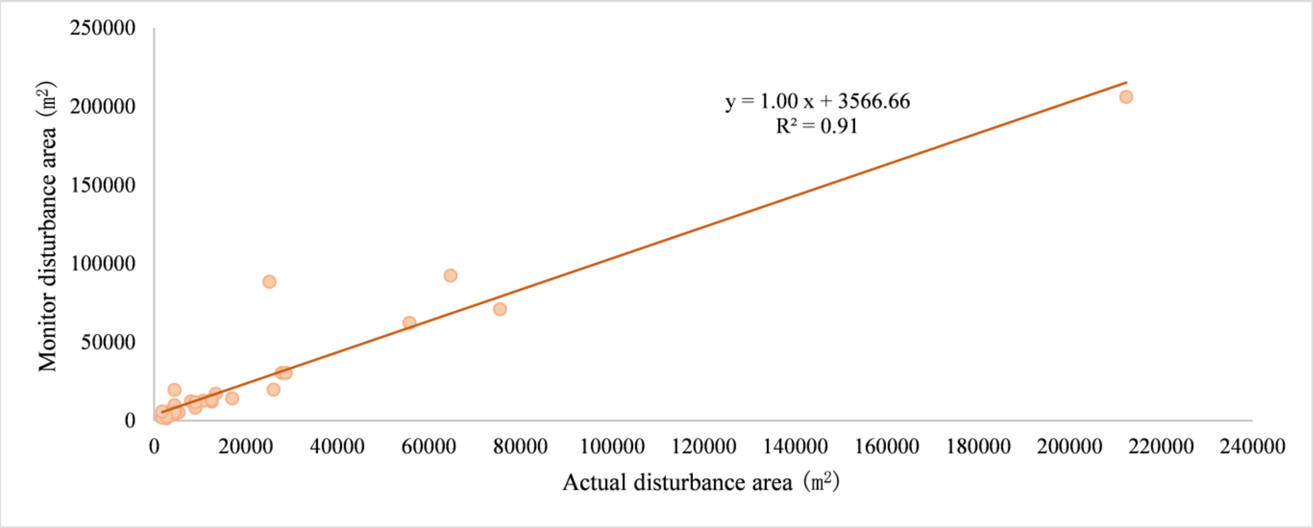


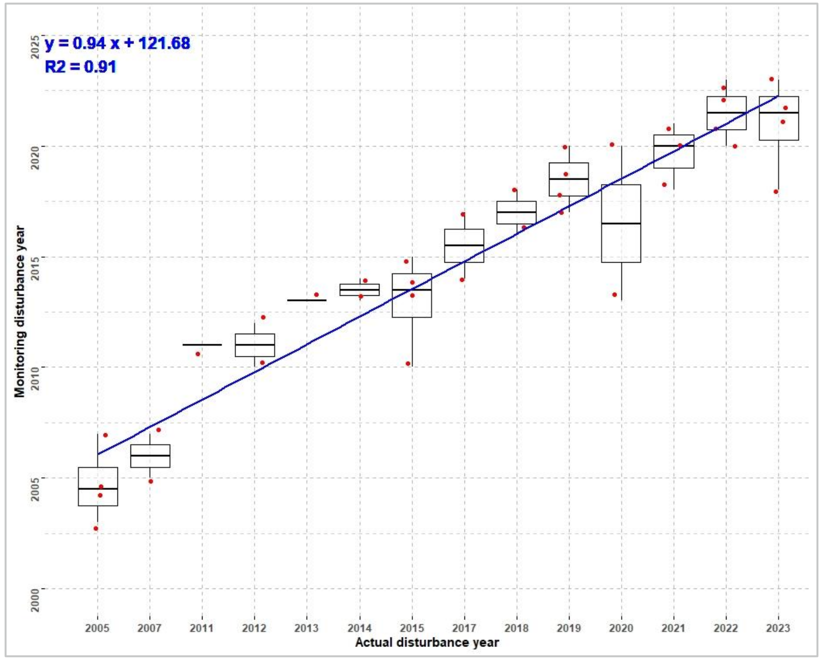
Time-series satellite remote sensing data for monitoring forest disturbances



Time-series satellite remote sensing data for monitoring forest disturbances

- According to 36 field survey data, remote sensing images and LandTrendr fitting curve were used to verify the disturbance monitoring results, and the accuracy of disturbance area was evaluated, and a scatter plot was drawn. This right figure shows the range of actual disturbance years and corresponding monitored disturbance years for 36 sample plots, and the linear fit is performed

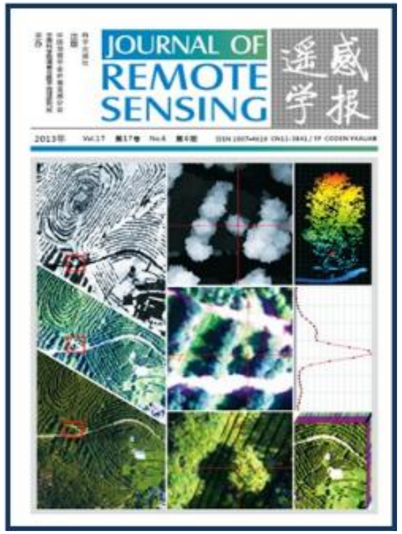


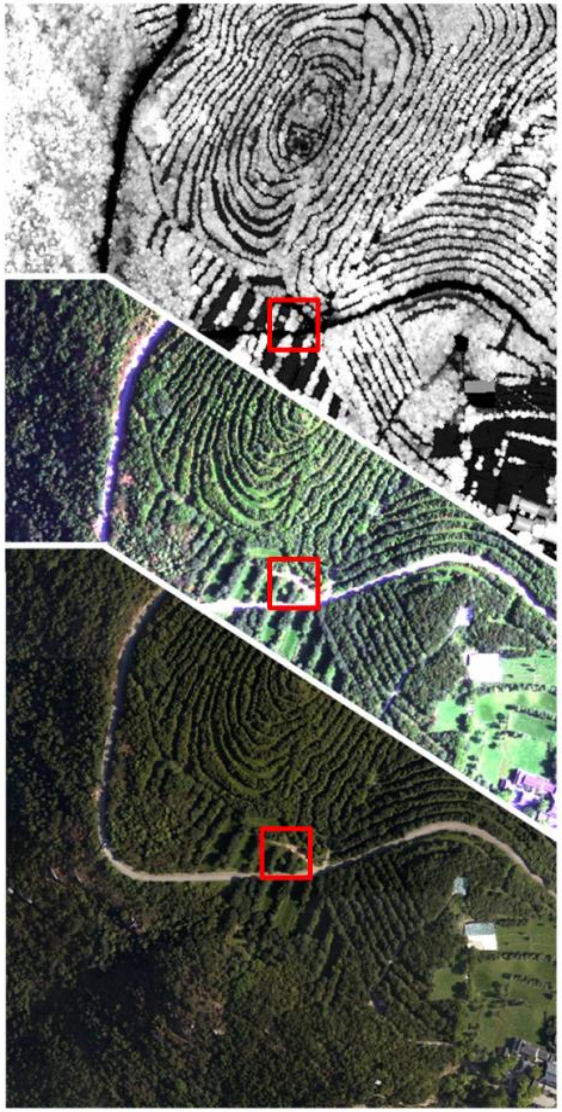


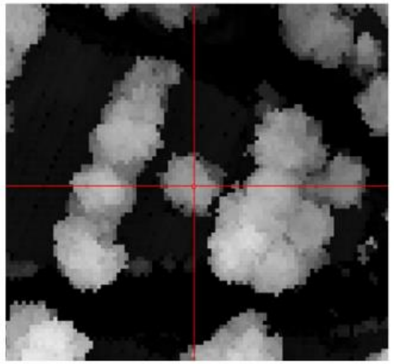
The disturbance area has good consistence, the slope of linear fitting is 1.00, R^2 is 0.91

The year of disturbance observed in the field is consistent with the year of forest disturbance monitored by remote sensing, the slope of linear fitting is 0.94, and the R^2 is 0.91

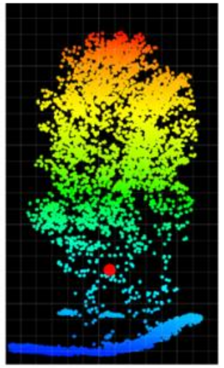
CAF Airborne remote sensing system



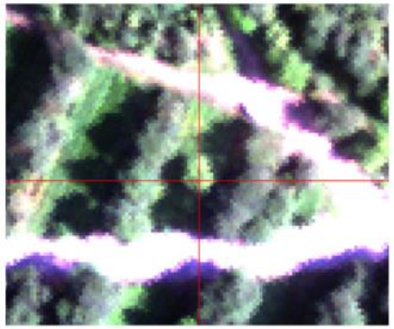




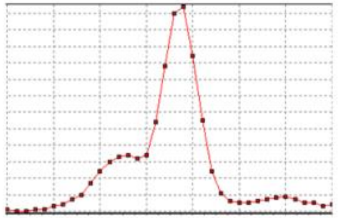
CHM image



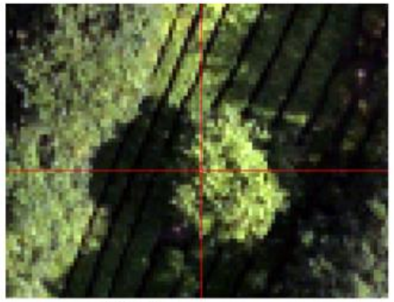
Side view of point cloud data



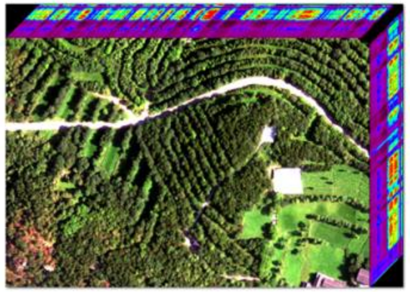
Hyperctral image



Single pulse waveform

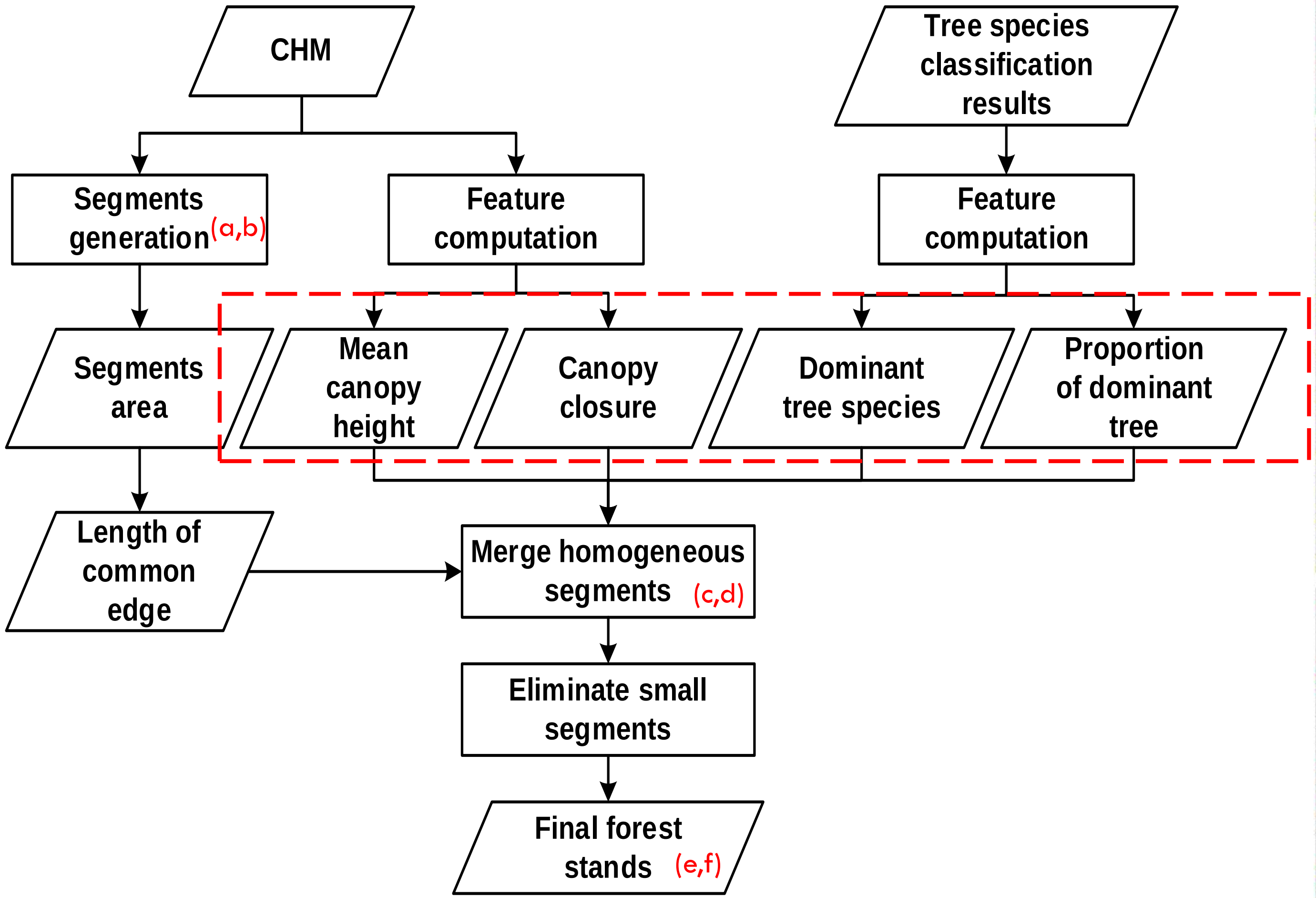


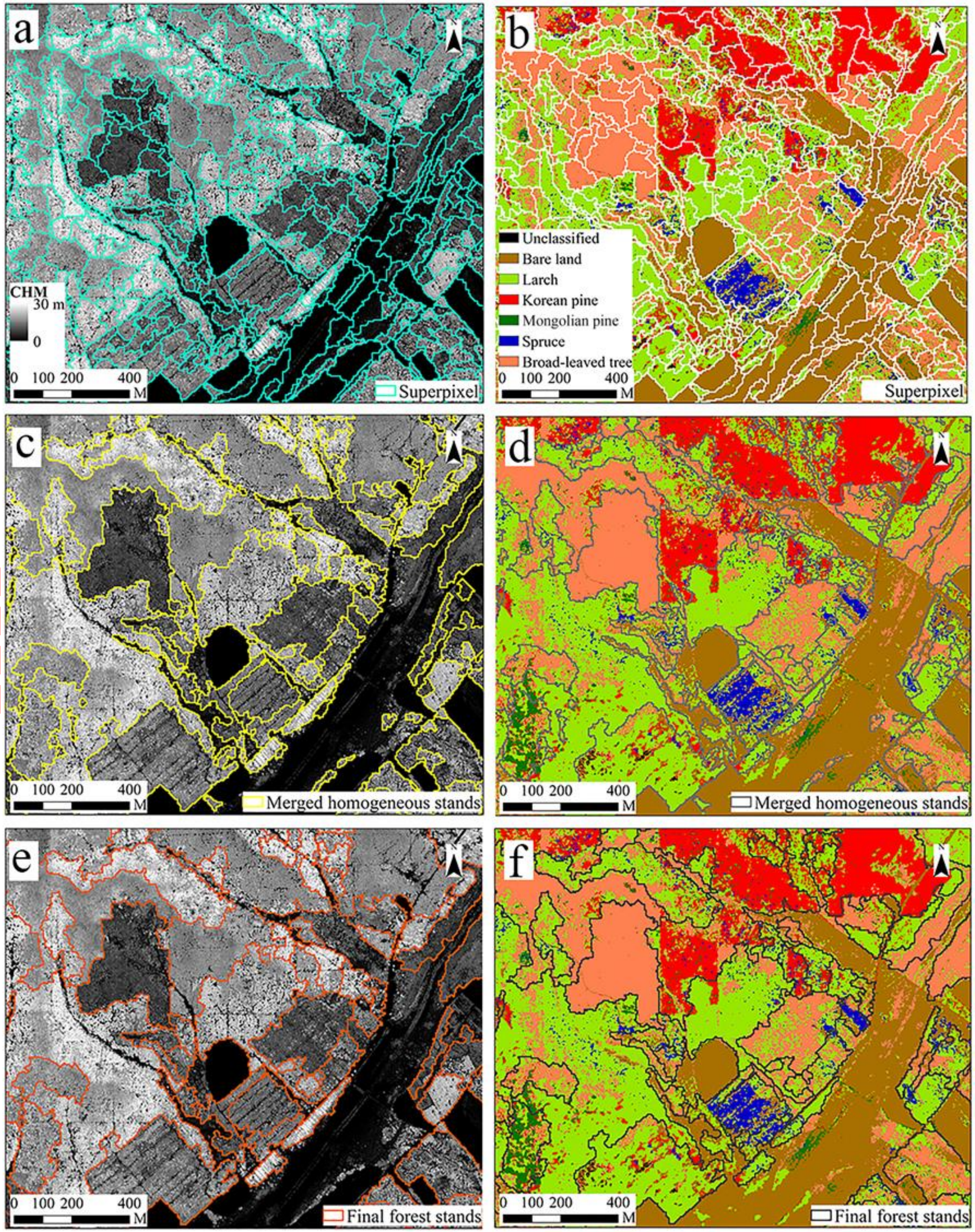
CCD image

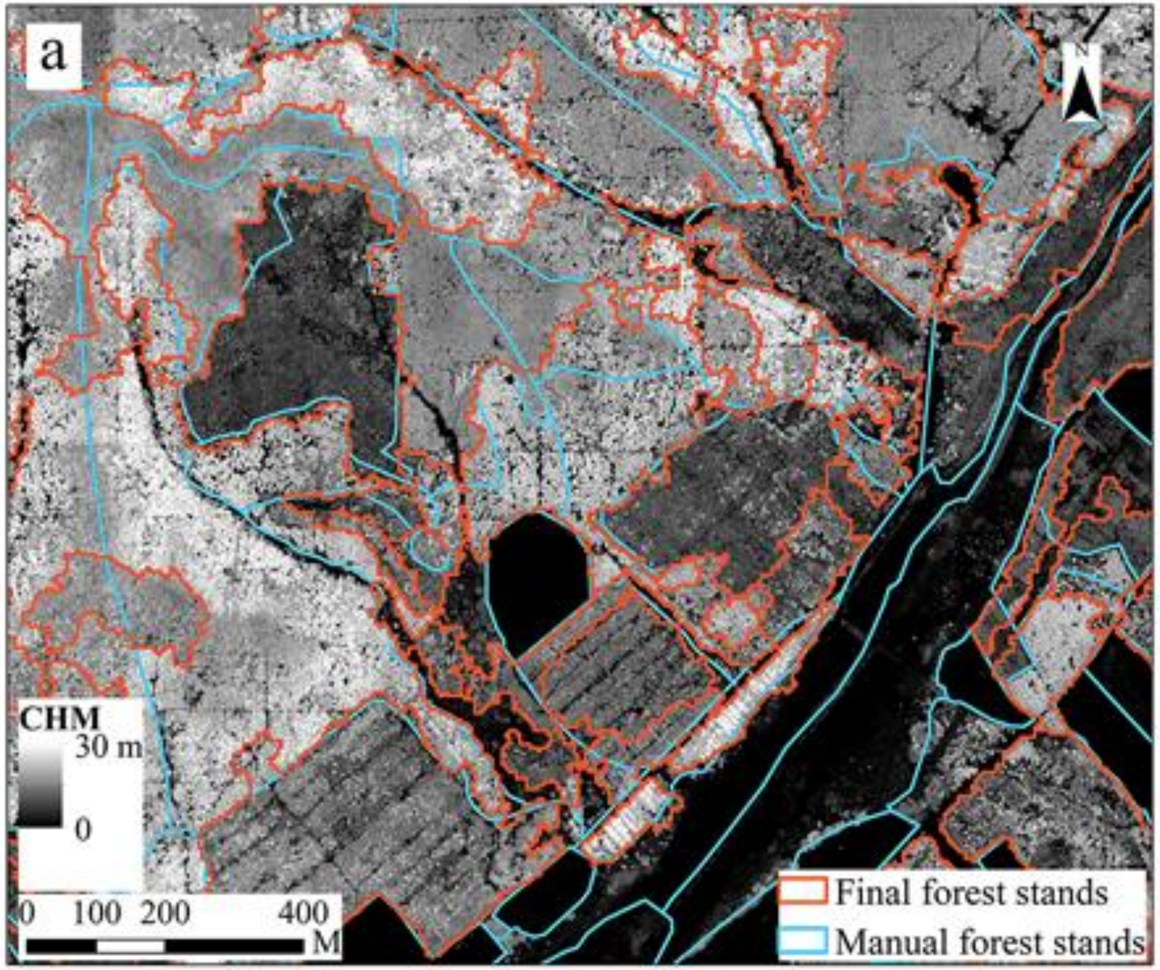


Hyperspectral spectrum cube

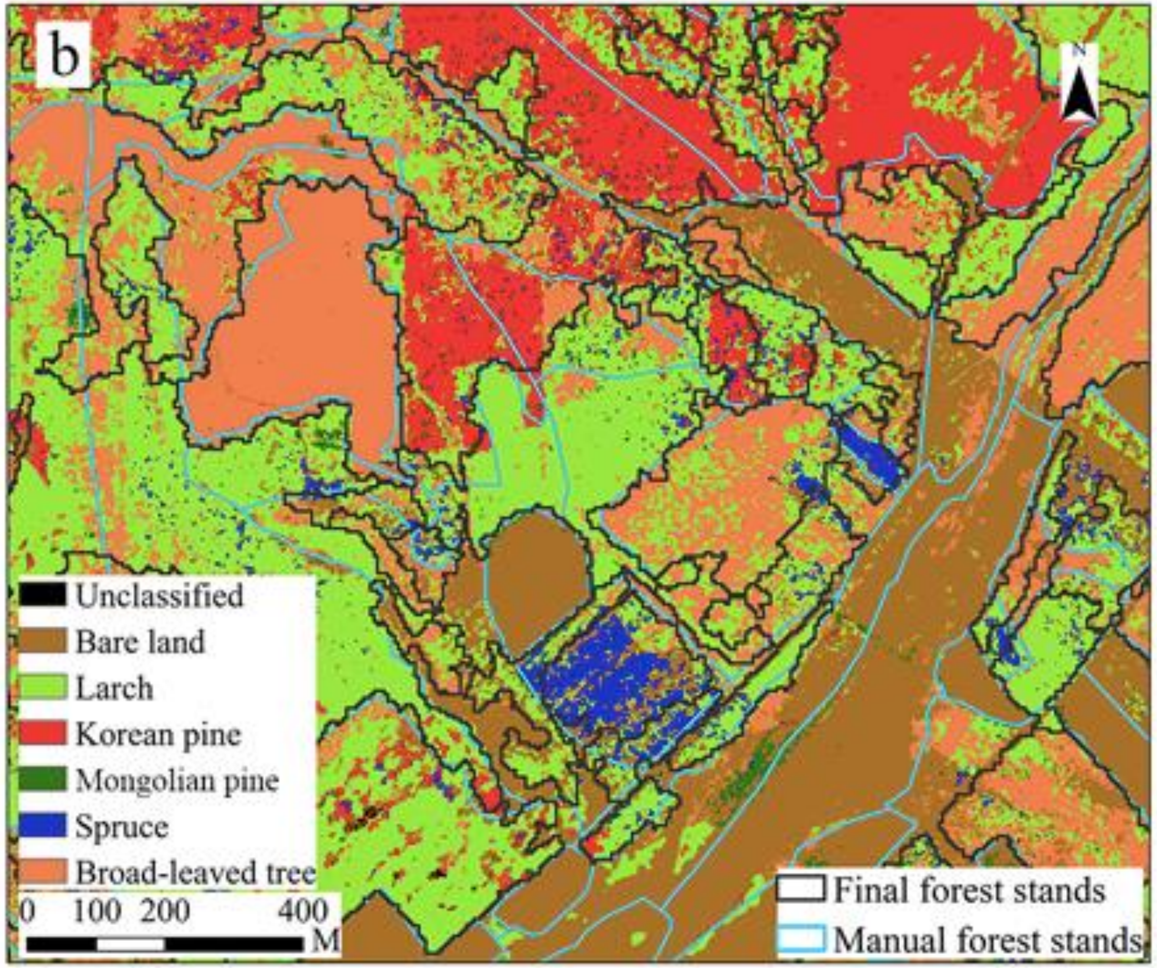
Automated Forest Stand Delineation







(a)The final forest stands(red line) and forest management inventory stands(blue line) on CHM

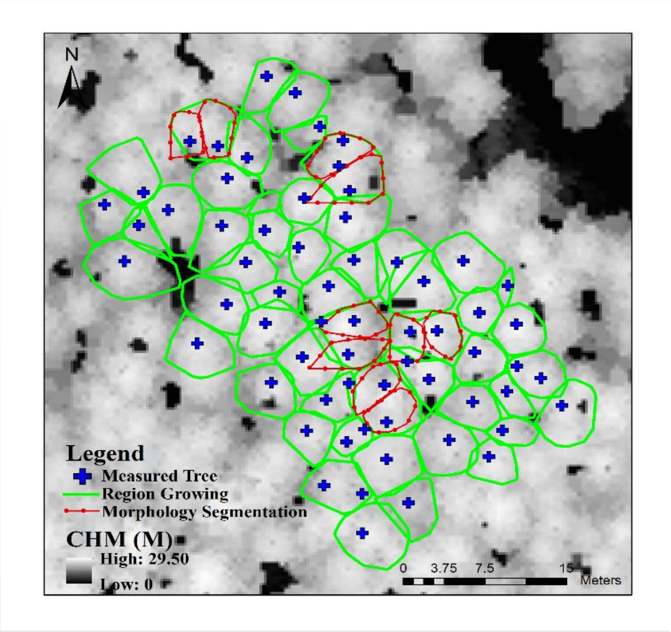


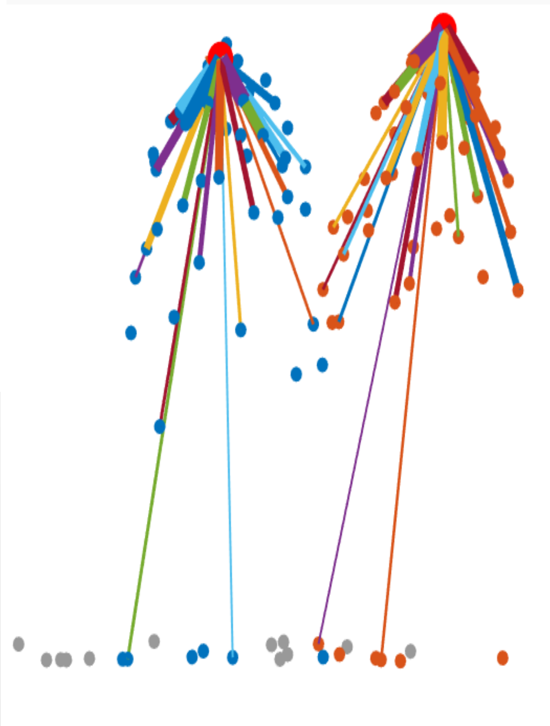
(b)The final forest stands(black line) and forest management inventory stands(blue line) on tree species map

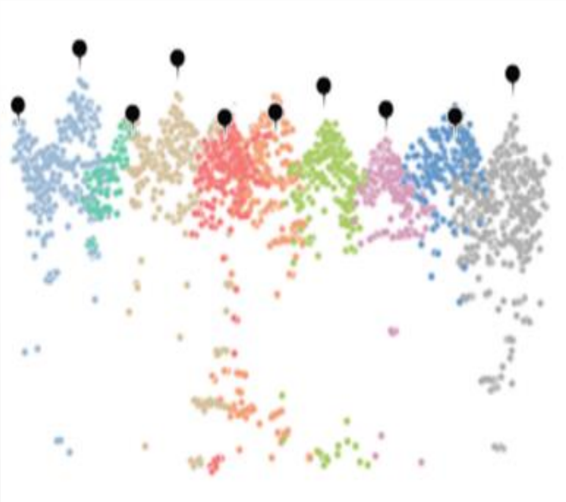
- The automatically delineated forest stands were consistent with forest management inventory stands in terms of shape and area, with better internal consistency and larger external variability.

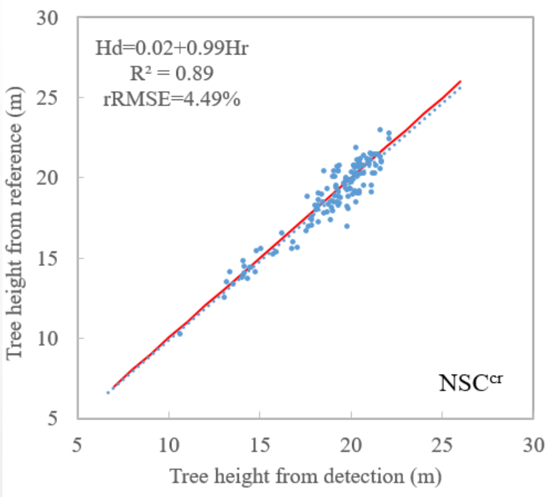
Xiong, H., Pang, Y., Jia, W., & Bai, Y. (2024). Forest stand delineation using airborne LiDAR and hyperspectral data. Silva Fennica, 58(2).

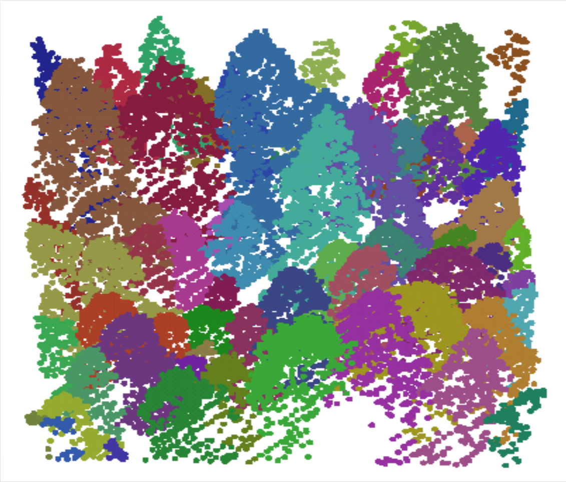
Individual tree segmentation using ALS

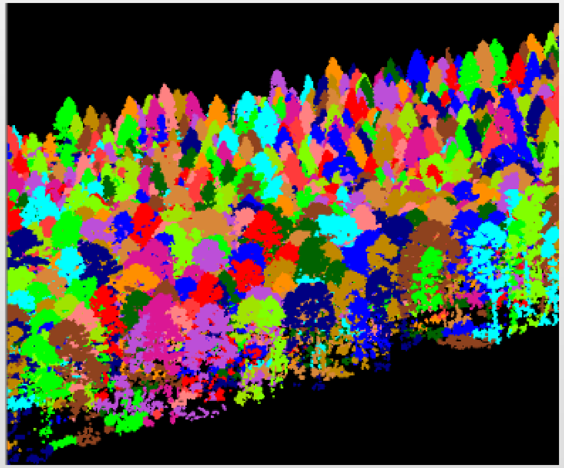


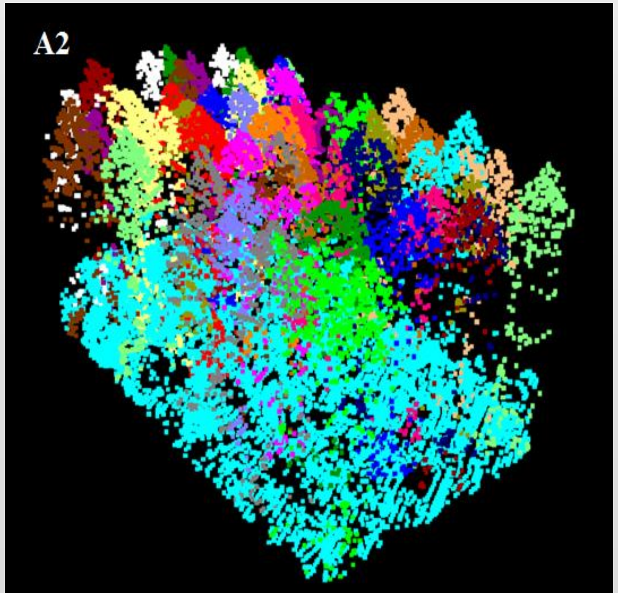








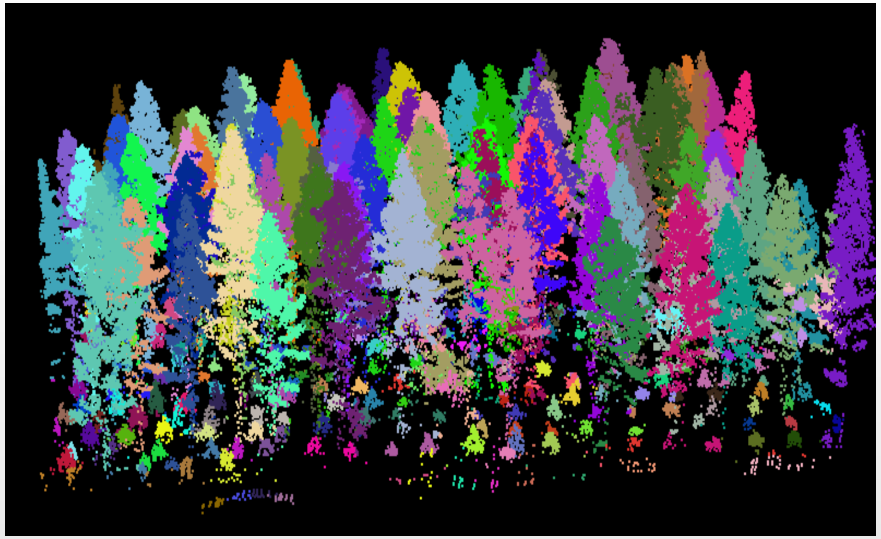


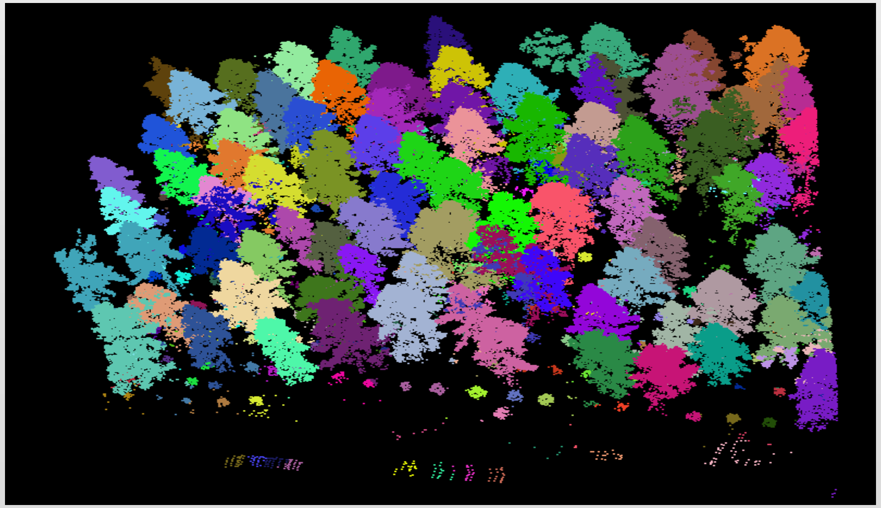


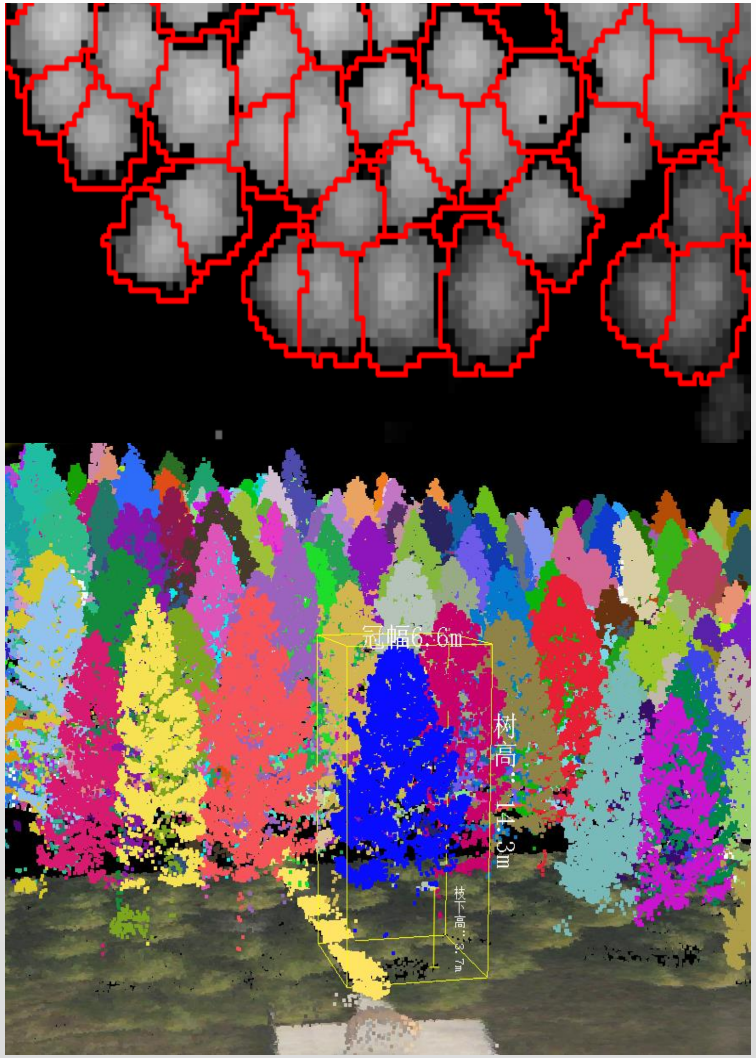
Ma, Z., Pang, Y., Wang, D., Liang, X., Chen, B., Lu, H., Weinacker, H., Koch, B. Individual Tree Crown Segmentation of a Larch Plantation Using Airborne Laser Scanning Data Based on Region Growing and Canopy Morphology Features. Remote Sens. 2020, 12, 1078.

Yong Pang, Weiwei Wang, Liming Du, Zhongjun Zhang, Xiaojun Liang, Yongning Li, Zuyuan Wang. 2021. Nyström-based spectral clustering using airborne LiDAR point cloud data for individual tree segmentation, International Journal of Digital Earth

Individual tree segmentation using ALS







AGB estimation using LBI and ALS data

Lidar Biomass Index (LBI)

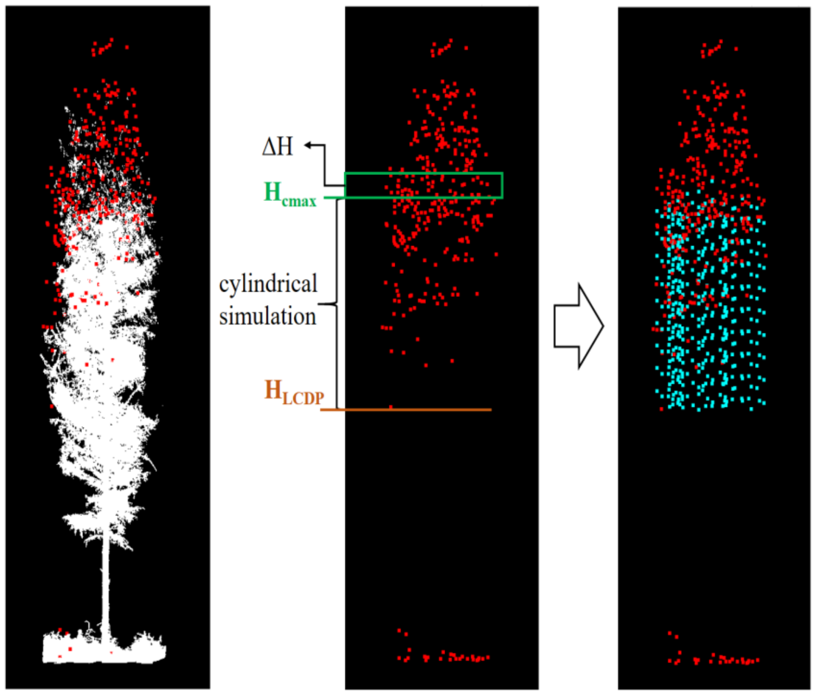
$$AGB = F\cdot\rho^{\beta}\cdot\pi^{\beta}\cdot H_T^{\beta}\left(\frac{1}{4}D^2\right)^{\beta} \qquad D^{\alpha} \propto \sum_{H_c}^{H_T} Cover(H)\cdot H$$

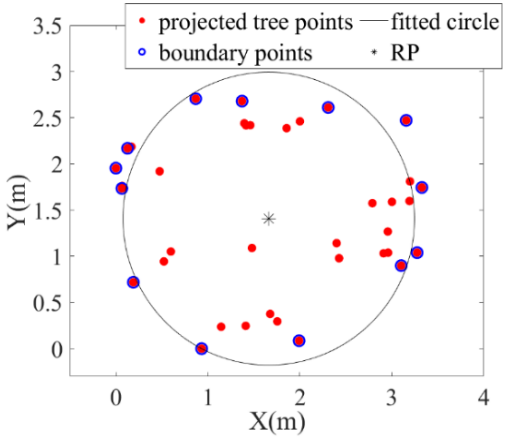
$$LBI = \lim_{\Delta H \to 0} \sum_{H=H_c}^{H_T} U_L(H)\cdot[r(H)]^2 \cdot \Delta H \cdot H$$

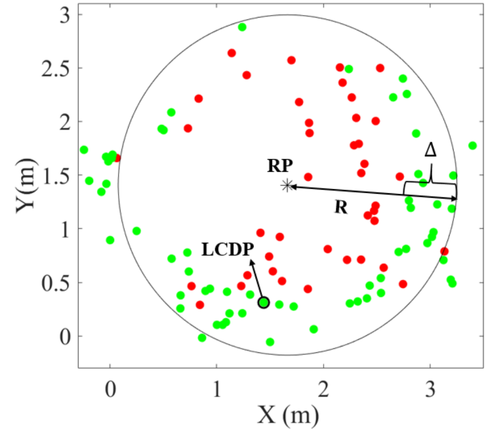
$$AGB = aLBI^{b} H_T^{\ c}$$

$$lnAGB = ln\kappa + \beta lnH_T + \frac{2\beta}{\alpha} lnLBI$$

***a*, β, κ** can be obtained by regression of a small amount of field measured data







points compensation of individual tree

Main step:

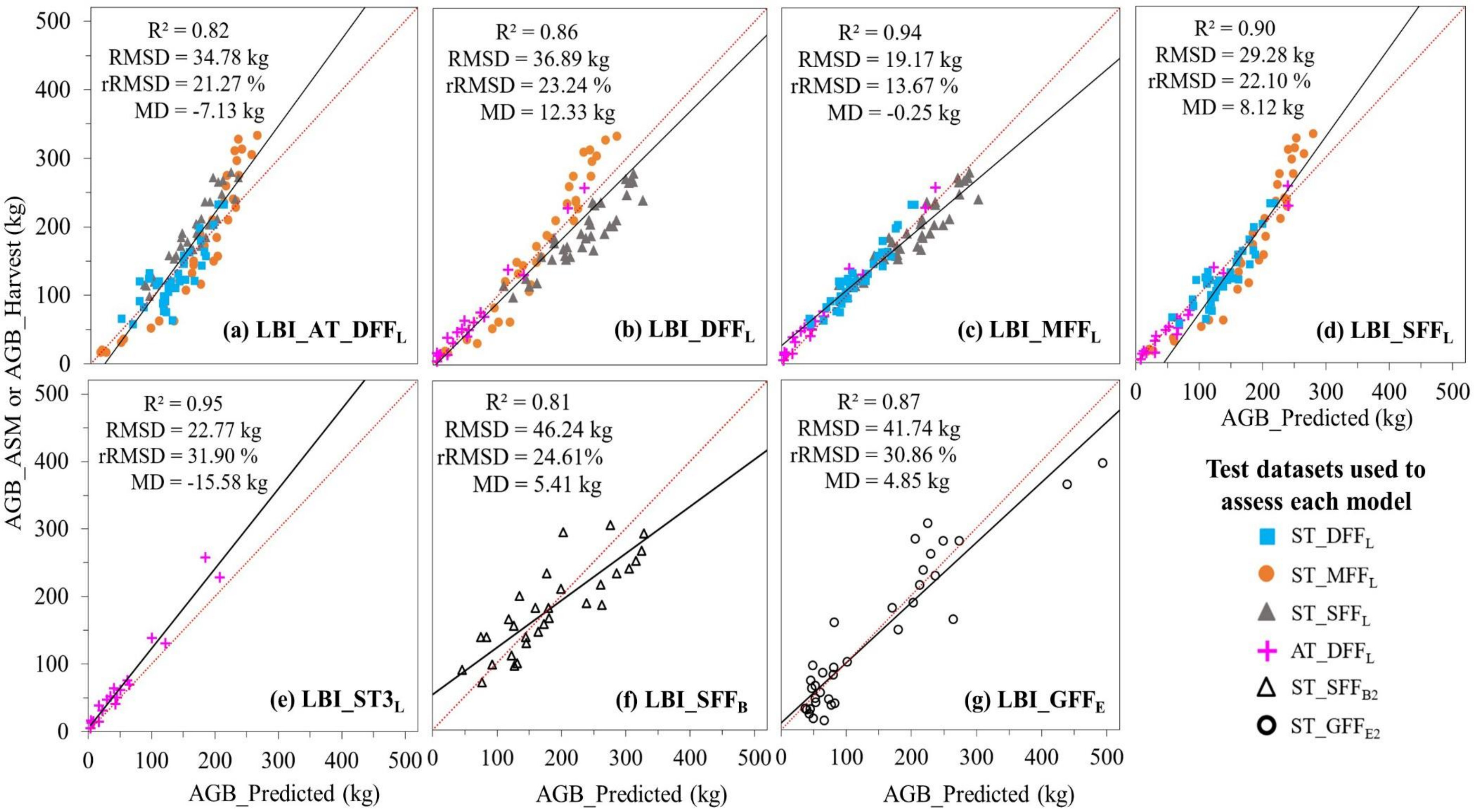
- Points compensation
- LBI and tree height calculation
- AGB calculation

Du L., Pang Y.* et al. 2023. An improved LiDAR Biomass Index (LBI) for efficient forest biomass mapping using airborne LiDAR data, Remote sensing of environment.

Individual tree level

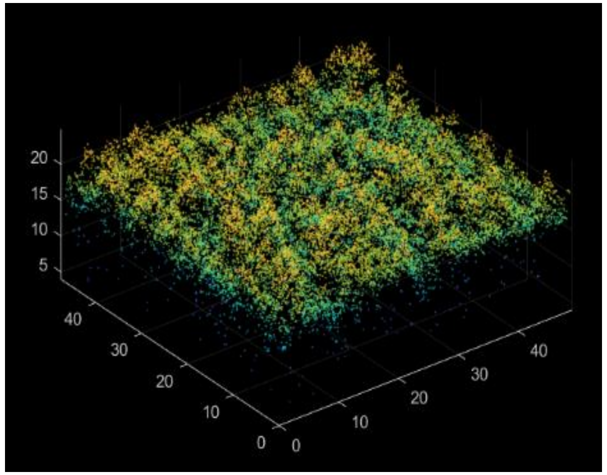
The LBI model was calibrated by selecting a small number of individual trees (35) from any forest farm.

AGB estimates derived using LBI-based models for the three tree species were close to ground measurements at the individual tree level. They explained 81% to 95% of the variance of independent test data not used to calibrate those models.

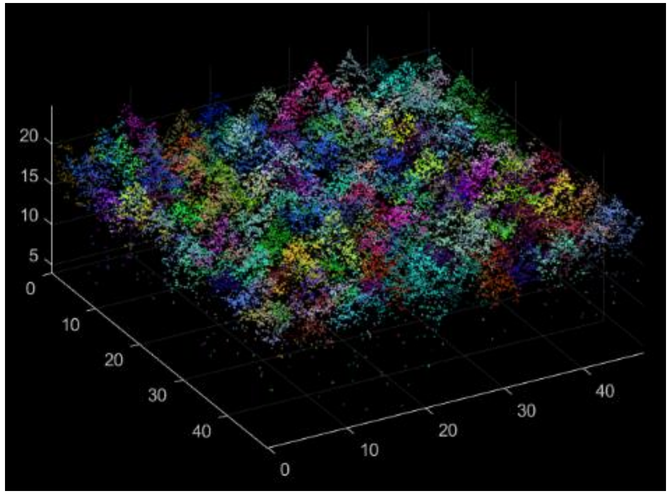


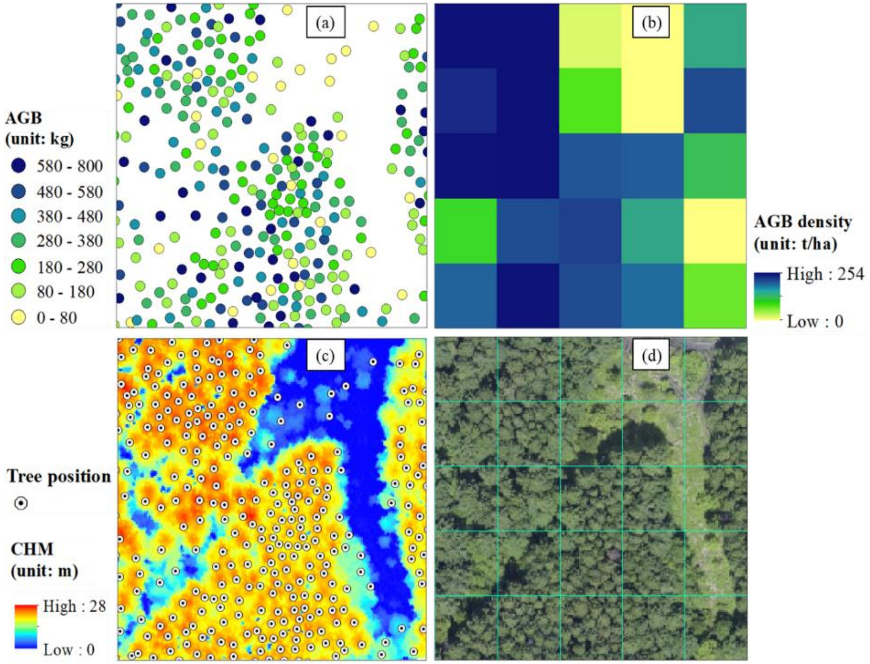
Du L., Pang Y.* et al. 2023. An improved LiDAR Biomass Index (LBI) for efficient forest biomass mapping using airborne LiDAR data, **Remote sensing of environment**.

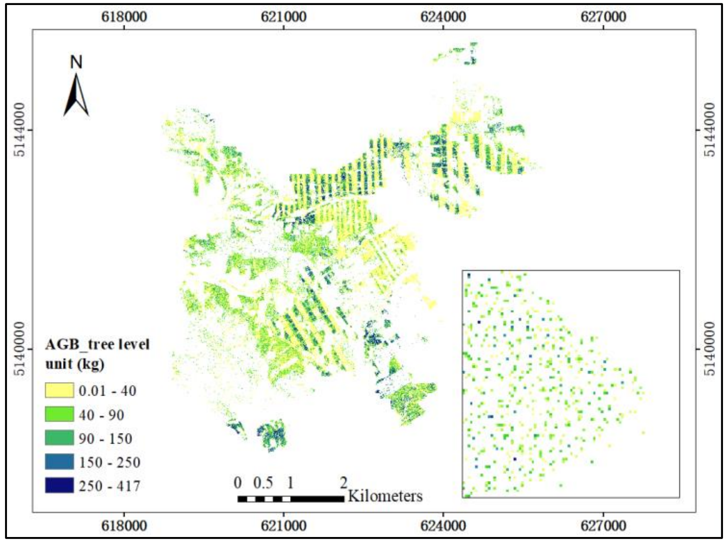
AGB estimation using LBI and ALS data



Individual tree segmentation







Biomass mapping of tree level

Du L., Pang Y.* et al. 2023. An improved LiDAR Biomass Index (LBI) for efficient forest biomass mapping using airborne LiDAR data, **Remote sensing of environment**.

Summary

- **Long time-series satellite remote sensing data detect forest disturbances history at large scale.**
- **Airborne remote sensing technologies provide stand level forest and tree parameters, which are fundamental for management treatment decision at forest management scale.**
- **Next: Link the remote sensing monitoring results to the forest management history and future treatments.**

Thank you!

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