Forest Aboveground Carbon Density Estimation using Lidar Remote Sensing Technology

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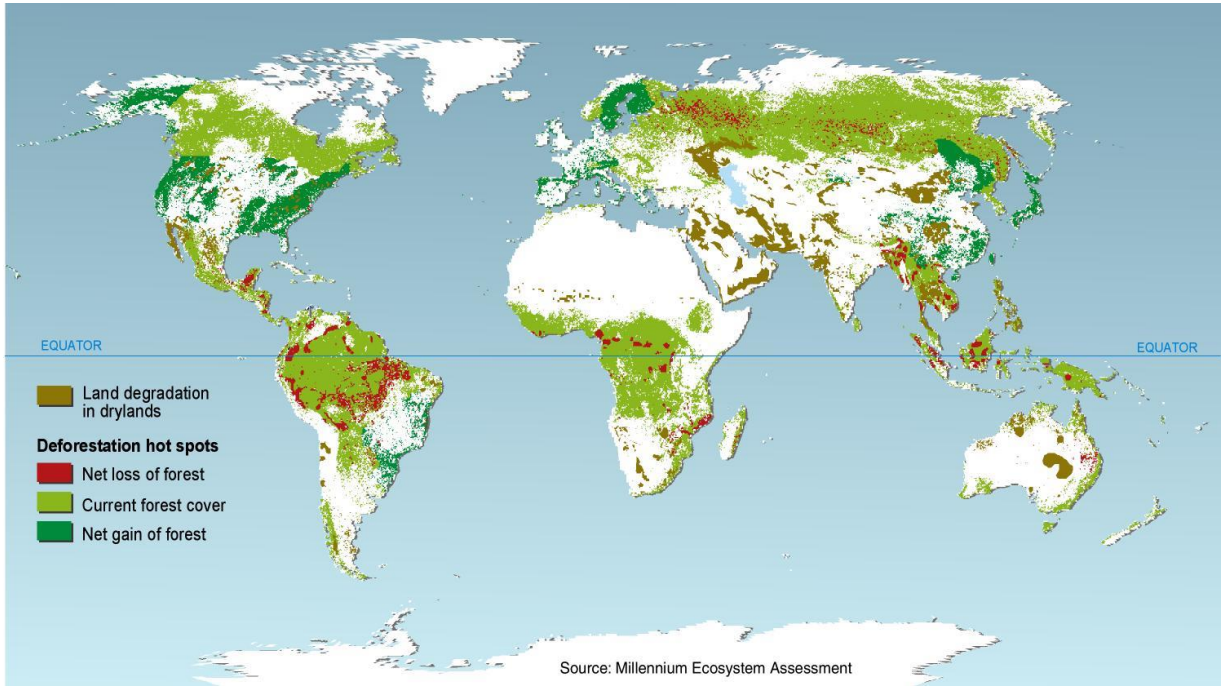
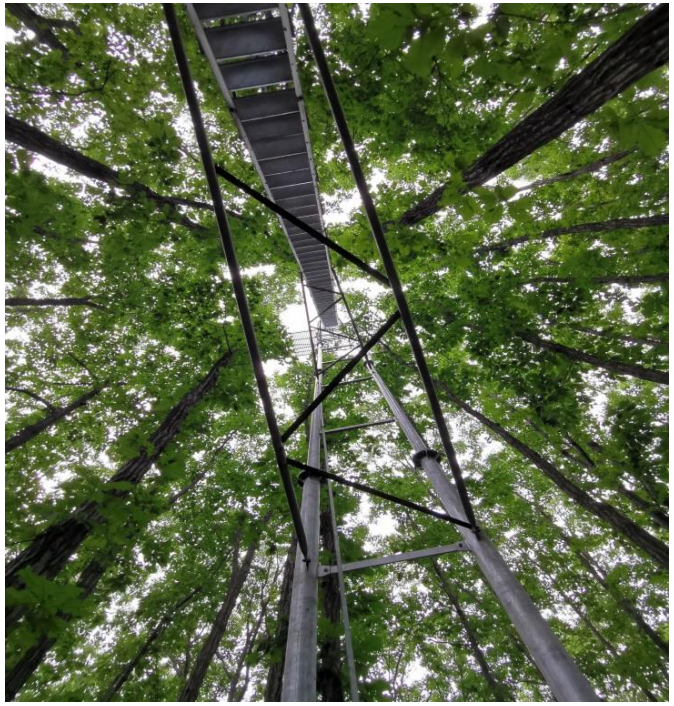
Outline

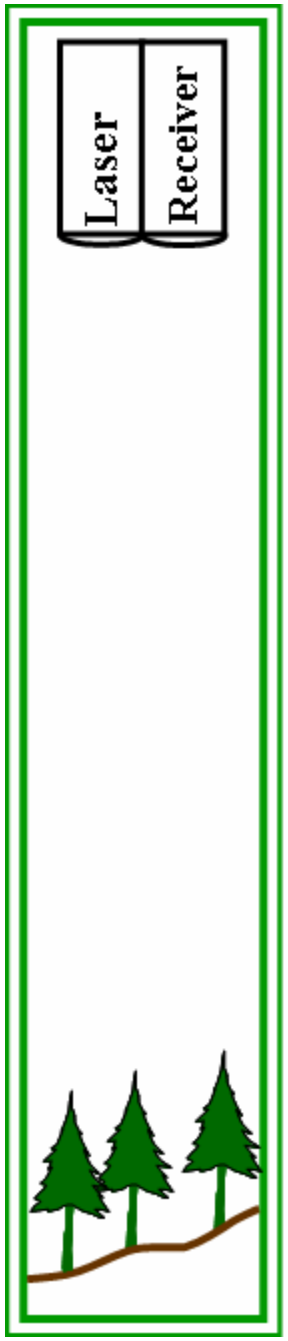
1. Lidar remote sensing and forest observation
2. Biomass estimation at individual tree level
3. Volume estimation at forest stand level
4. Carbon density estimation at regional level
5. Summary

Characteristics of Forest Resources





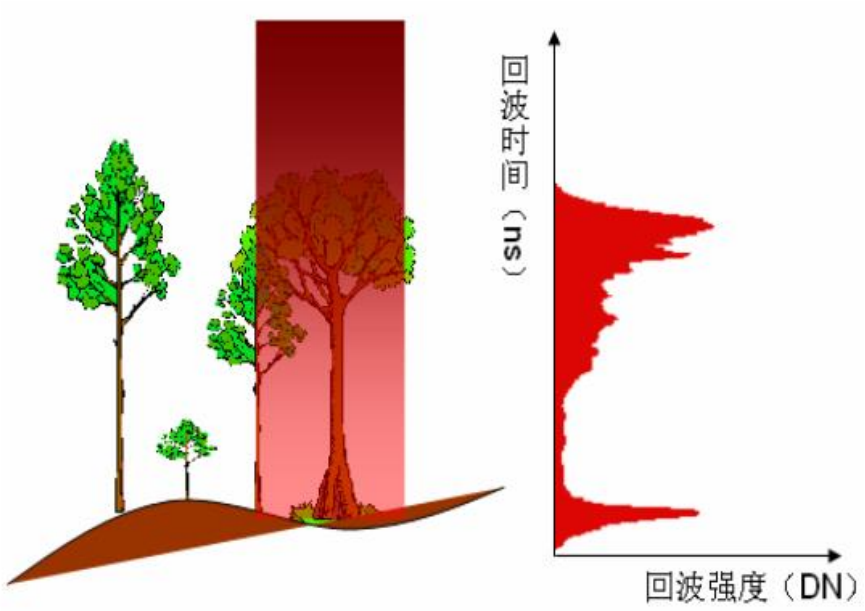
- **Wide distribution**
- **Vertical complexity**
- **Species diversity**



Lidar remote sensing principle

$$R = (c \cdot t)/2$$

– Light Detection And Ranging
– Laser Imaging Detection and Ranging (wiki)
~ LiDAR, Lidar



Lidar: Platforms

A timeline

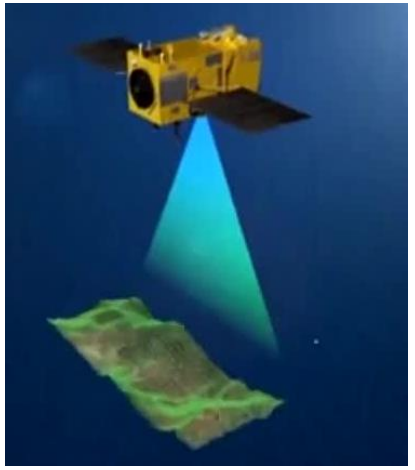
- Airborne Laser Scanning (ALS): 1990s
- Terrestrial Laser Scanning (TLS): 2000s
- UAV Laser Scanning (UAV-LS): 2010
- Mobile Laser Scanning (MLS): 2013
- Personal Laser Scanning (PLS): 2013

USA Satellite Mission

- ICESat-1 Geoscience Laser Altimeter System (GLAS)
- ICESat-2 ATLAS (2018 -)
- ISS GEDI (2018 -)

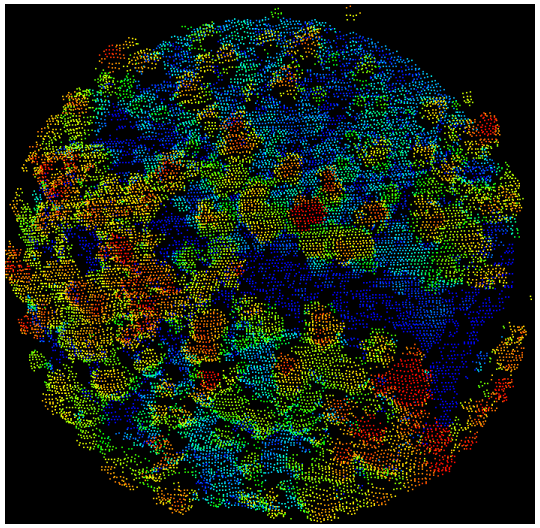
Chinese Satellite Mission

- Gaofen-7 (2019 -)
- Chinese Terrestrial Ecosystem Carbon Monitoring Satellite (2022 mission)

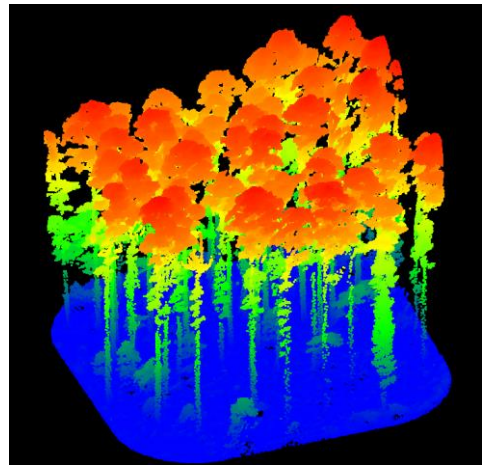


Lidar: Platforms

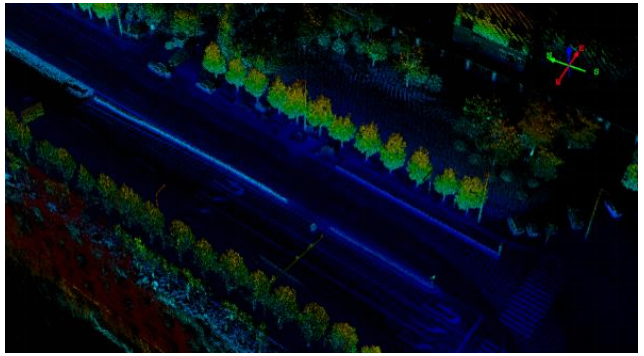
ALS



UAV



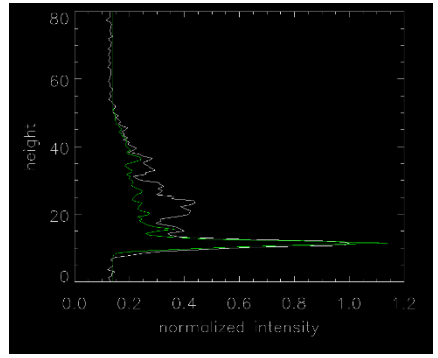
MLS



PLS

TLS

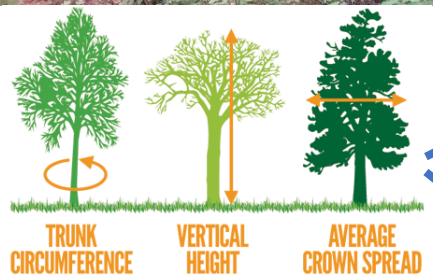
SLS



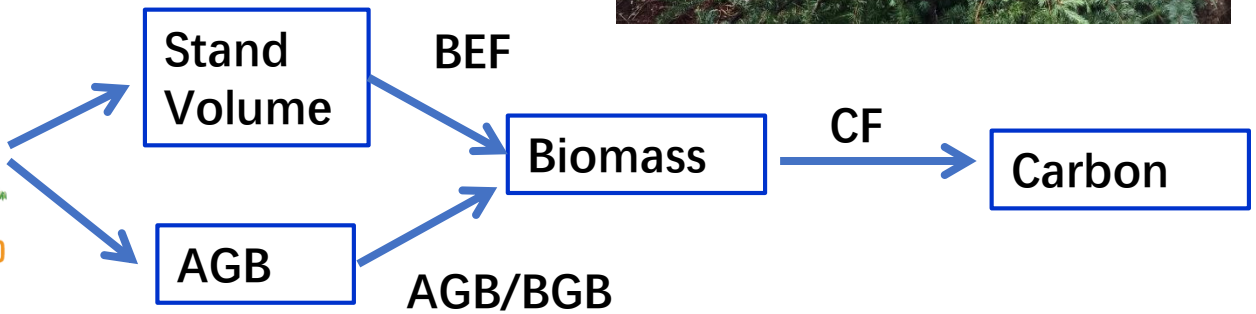
Allometric equation development for volume/biomass/carbon modelling

H ~ f(dbh)
V ~ f(dbh)
V ~ f(dbh, h)

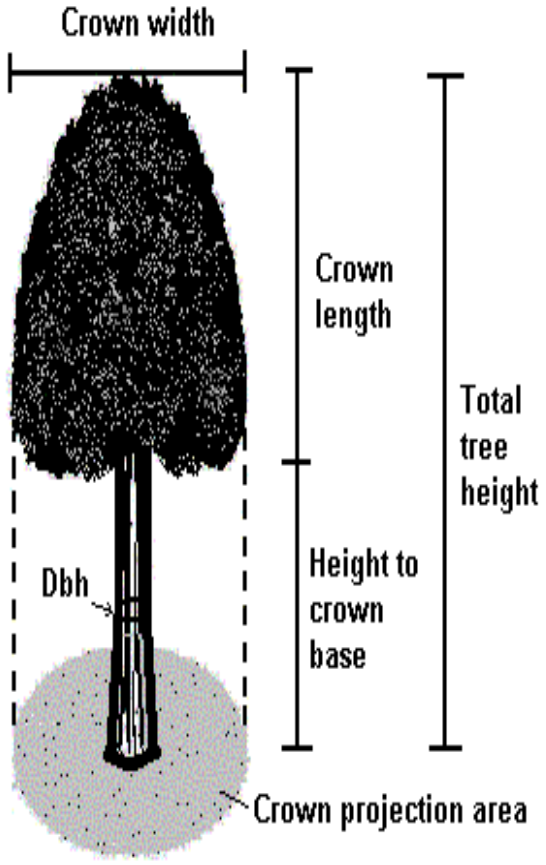
AGB ~ f(dbh)
AGB ~ f(dbh, h)



Field measurements



Measure forest parameters from Lidar data



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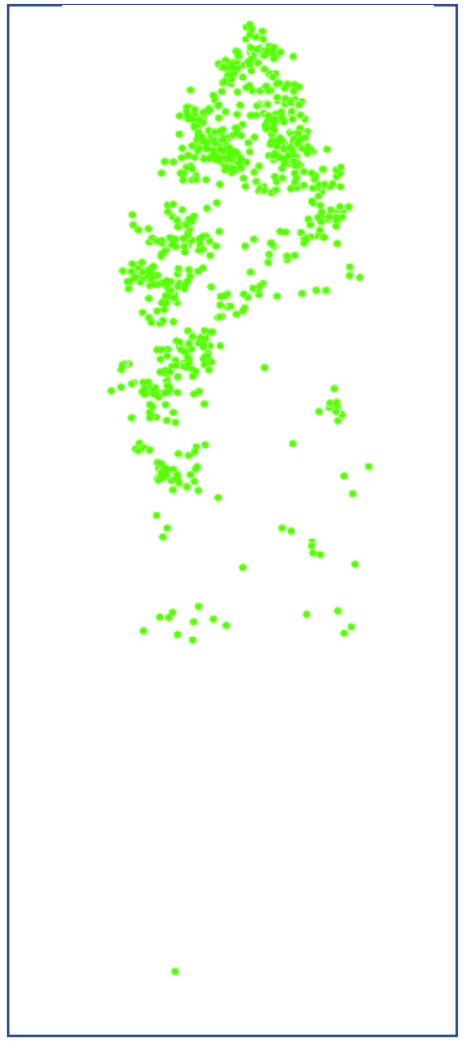
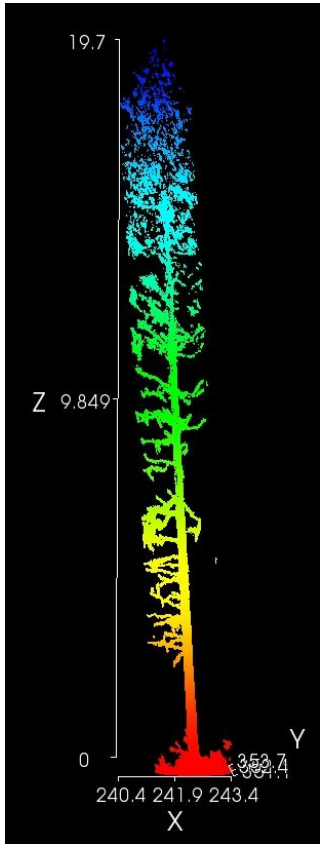
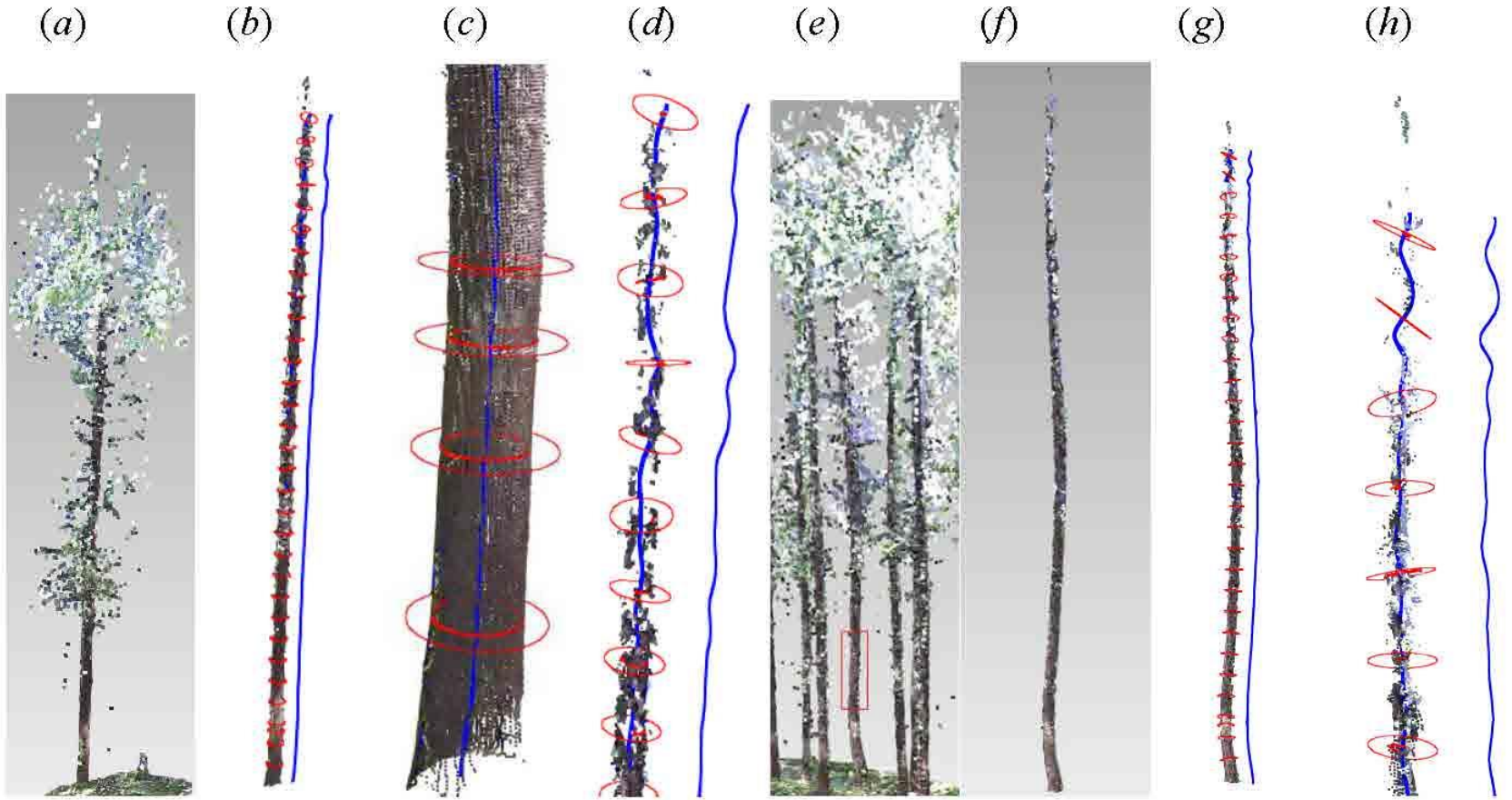


H ~ f(dbh)

dbh ~ f(H)

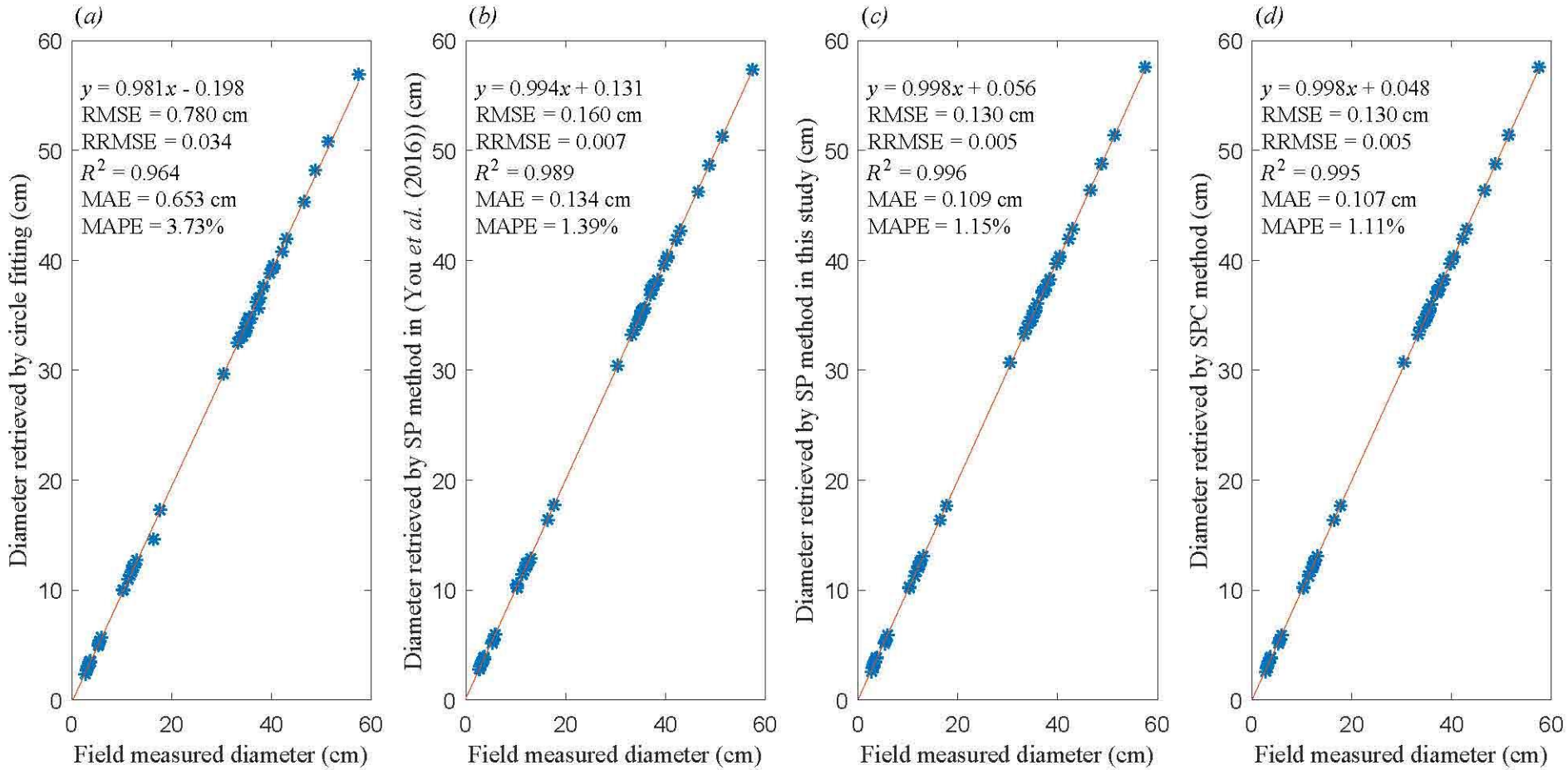
Measure DBH, H using TLS



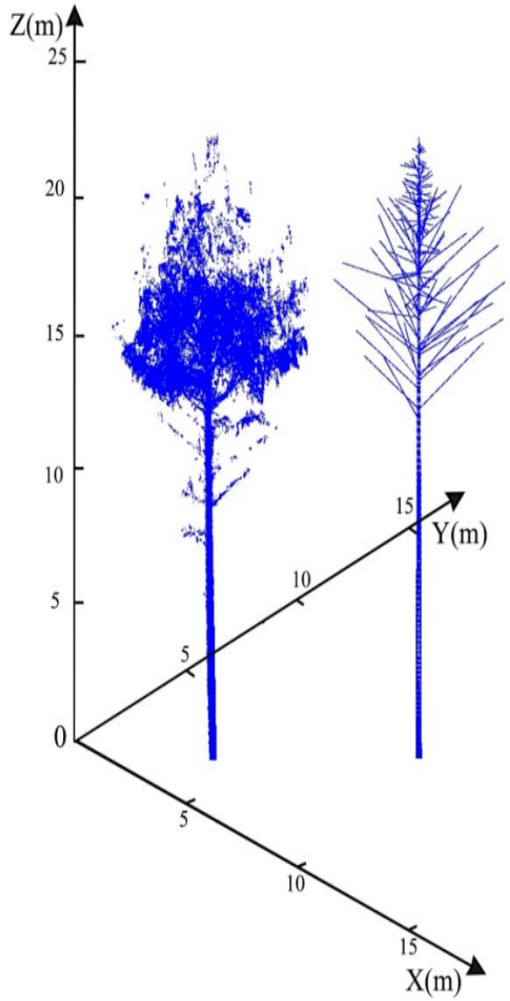


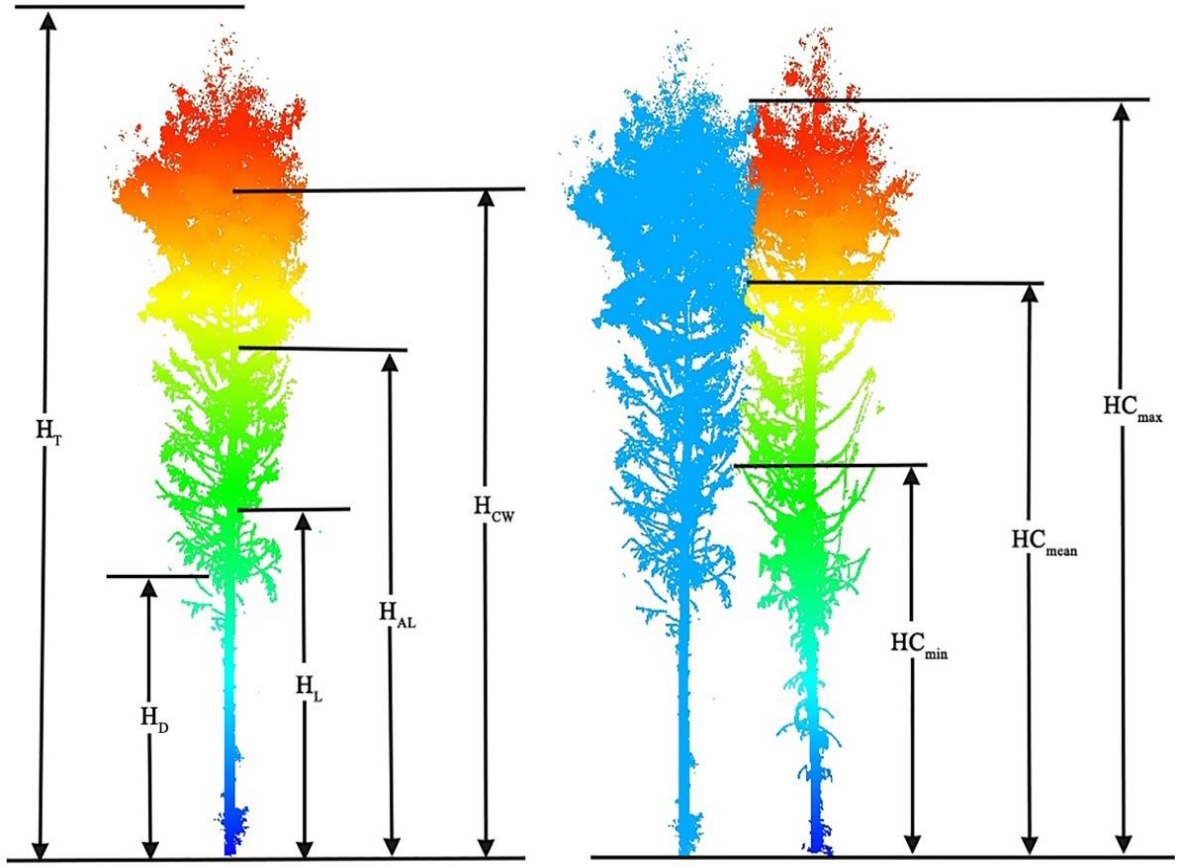
You, Lei, Jianwei Guo, Yong Pang, Shouzheng Tang, Xinyu Song, and Xiaopeng Zhang. 2021. “3D stem model construction with geometry consistency using terrestrial laser scanning data.” International Journal of Remote Sensing.

Measure DBH, H using TLS



LBI - Lidar Biomass Index



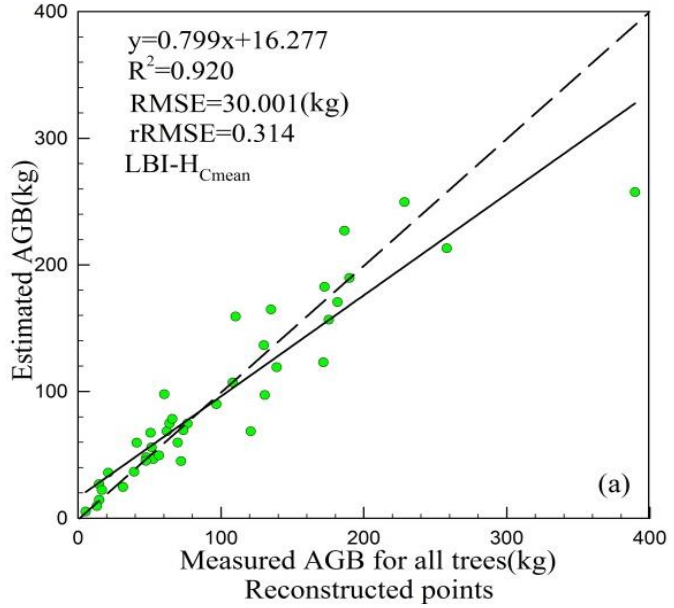


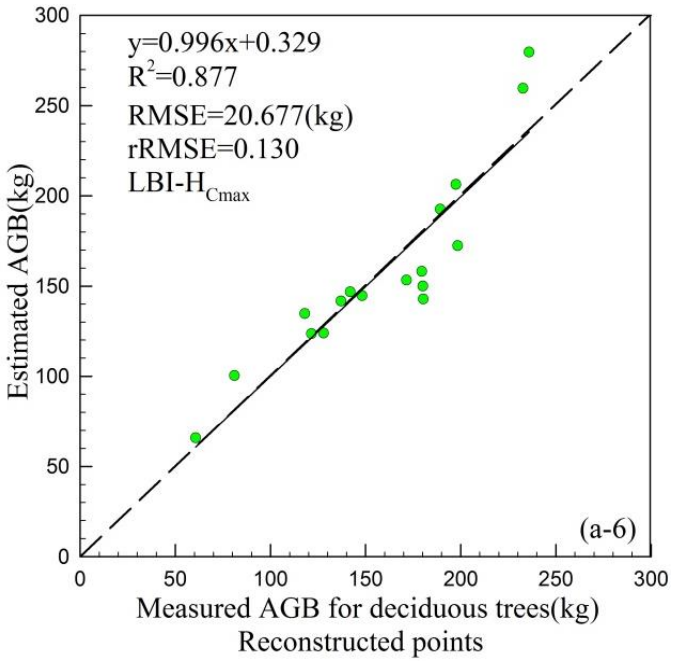
$$LBI = \lim_{\Delta H \to 0} \sum_{H=H_c}^{H_T} U_L(H) \cdot \left[r(H) \right]^2 \cdot \Delta H \cdot H$$

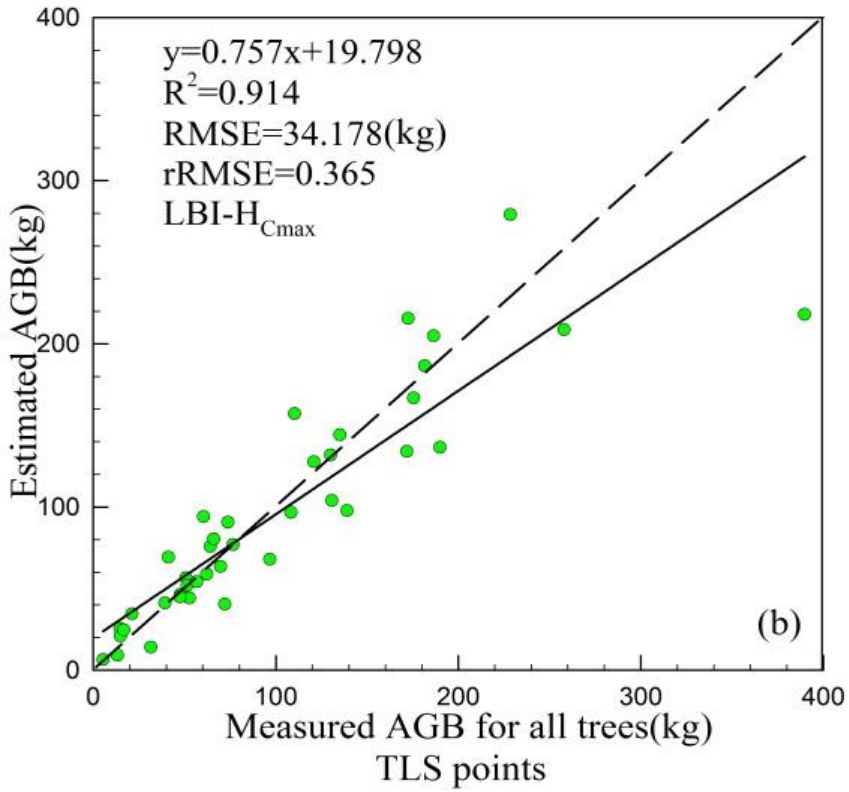
Use height and crown size information.

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

LBI - Lidar Biomass Index

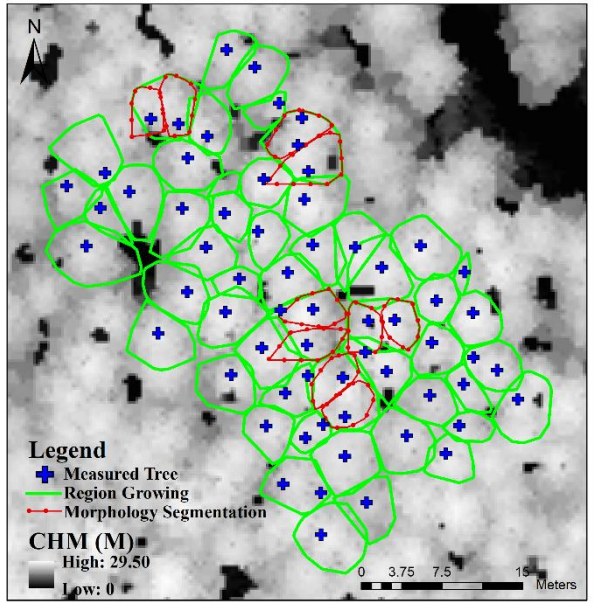


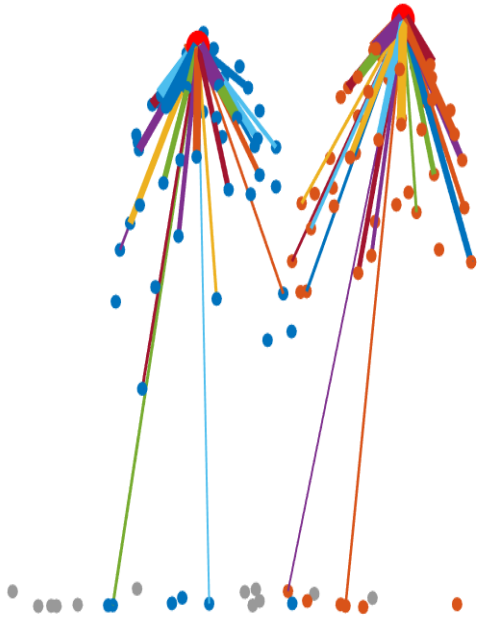


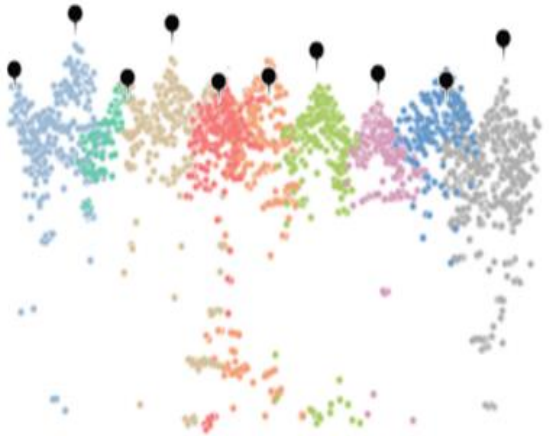


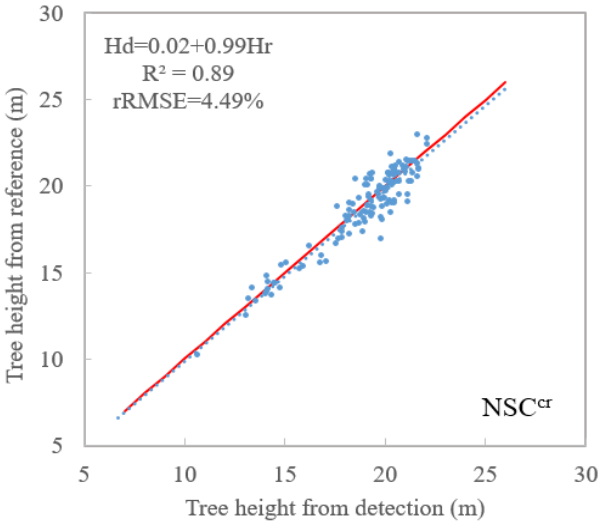
Wang Q., Pang Y.* et al. 2021. Lidar Biomass Index: a novel solution for tree-level biomass estimation using 3D crown information, **Forest Ecology and Management**

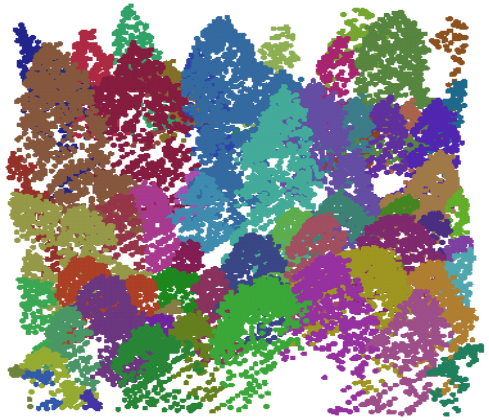
Individual tree segmentation using ALS

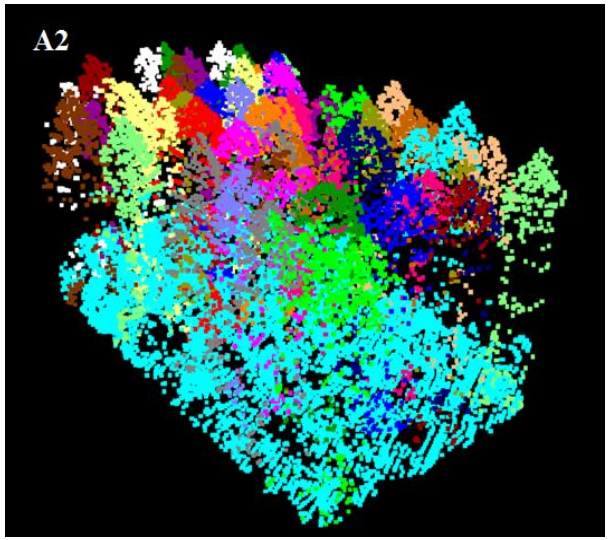


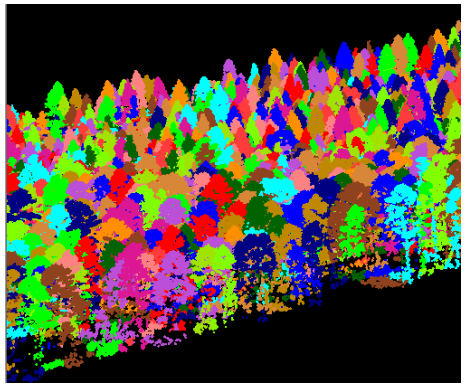










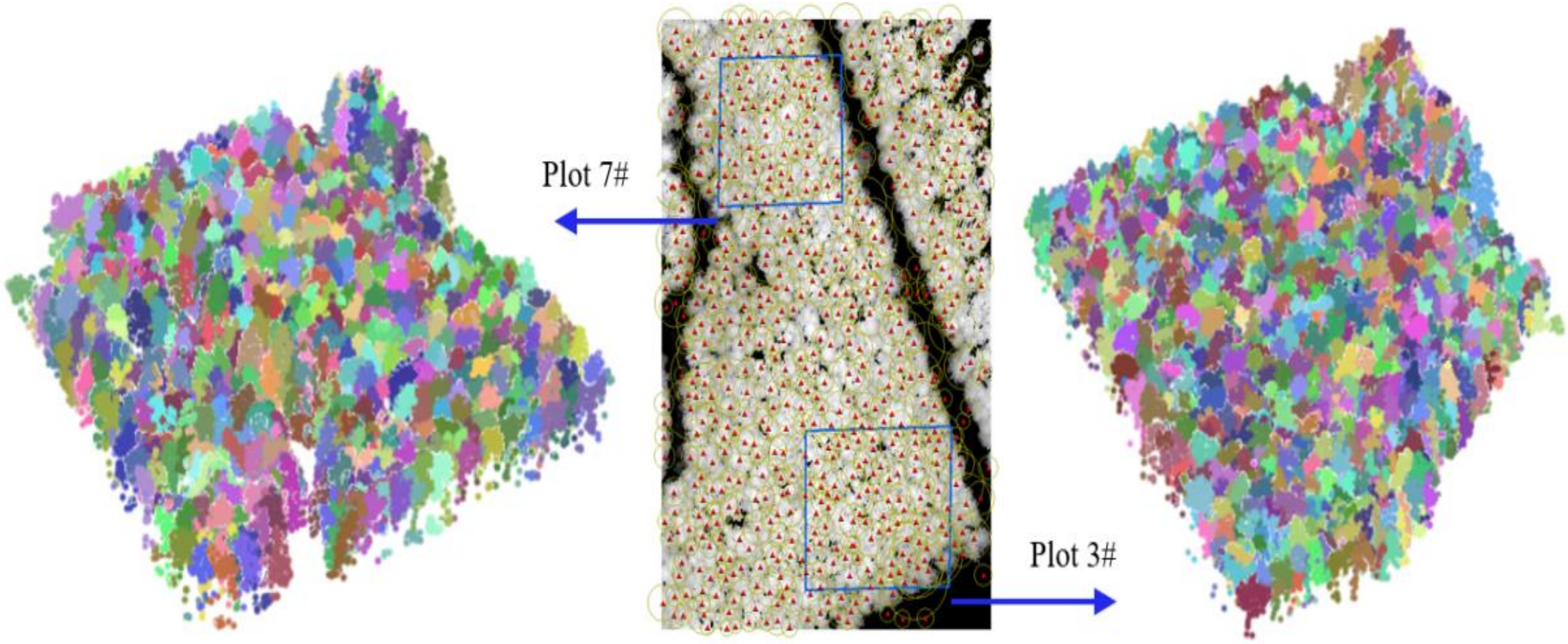


王伟伟，庞勇, 张钟军, 梁晓军. 2021. 基于谱聚类算法的机载LiDAR点云单木分割.遥感学报

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.

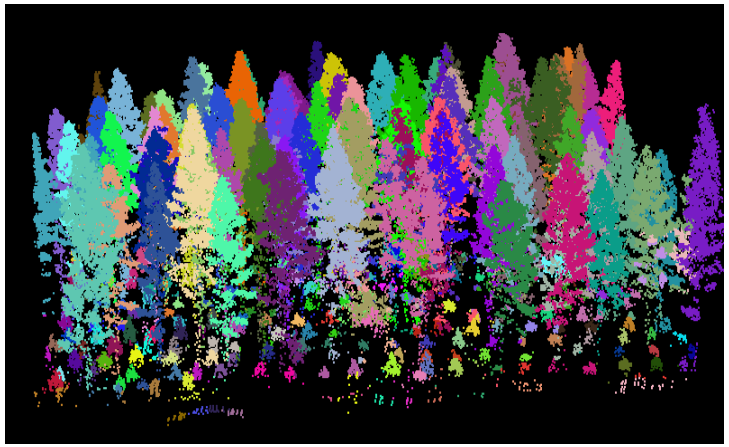
Yong Pang, Weiwei Wang, Liming Du, Zhongjun Zhang, Xiaojun Liang, Yongning Li, Zuyuan Wang. 2021. Nyström-based spectral clustering using airborne LiDAR point cloud data for individual tree segmentation, International Journal of Digital Earth

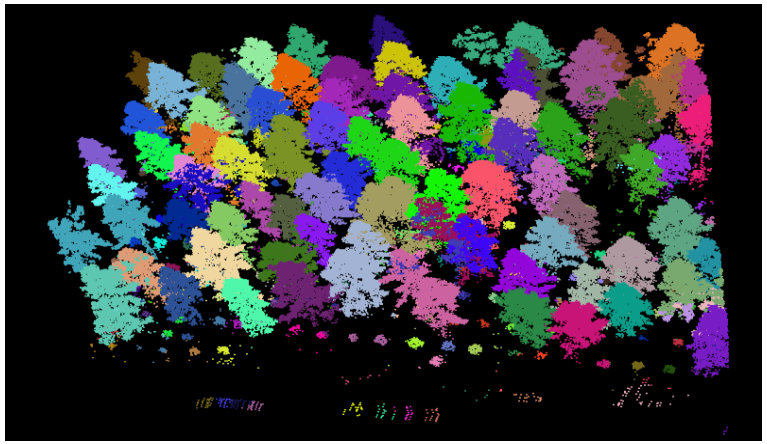
Individual tree segmentation using ALS

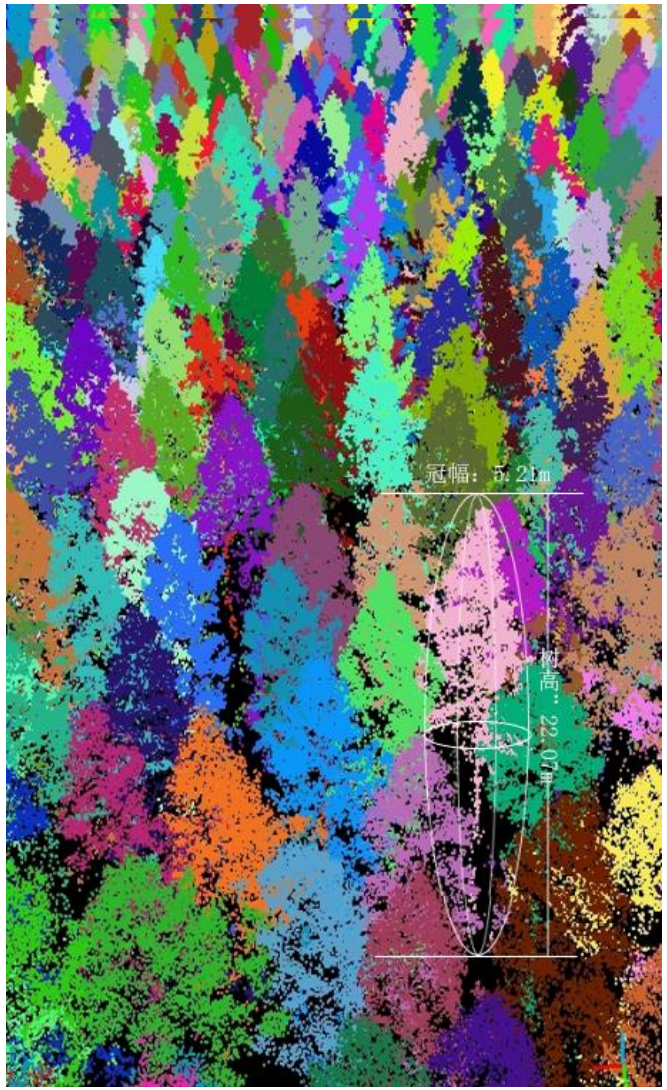


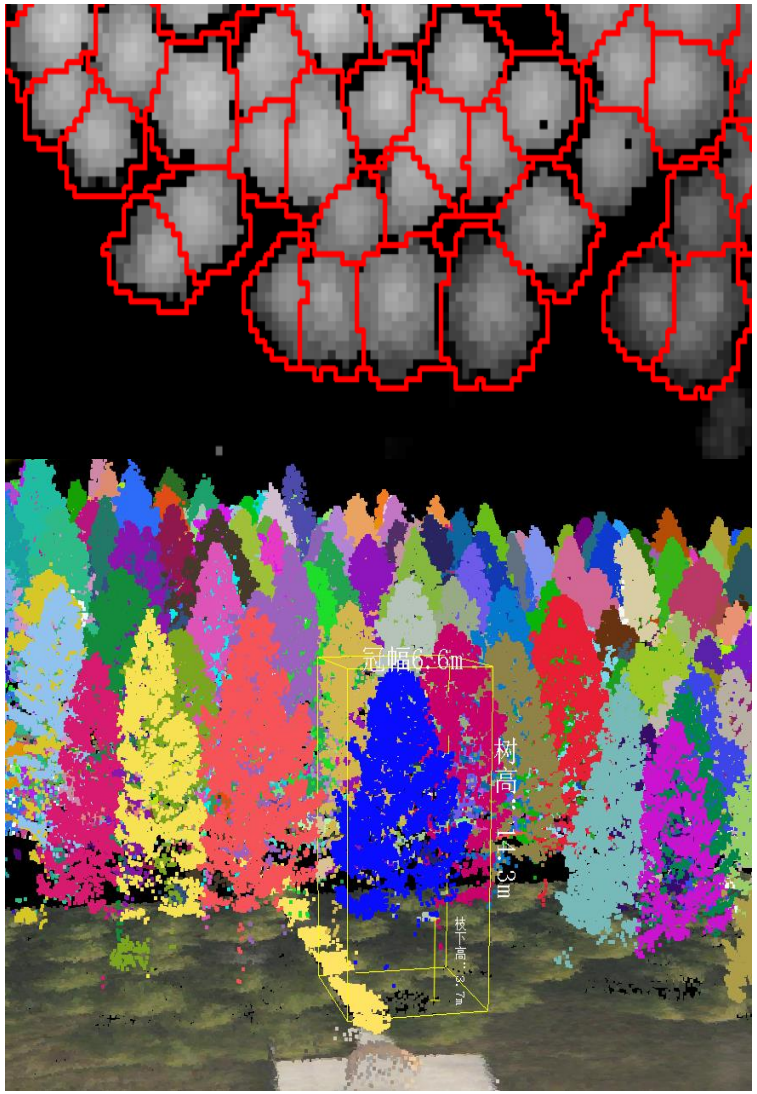
Yong Pang, Weiwei Wang, Liming Du, Zhongjun Zhang, Xiaojun Liang, Yongning Li, Zuyuan Wang (2021) Nyström-based spectral clustering using airborne LiDAR point cloud data for individual tree segmentation, International Journal of Digital Earth

Individual tree segmentation using ALS



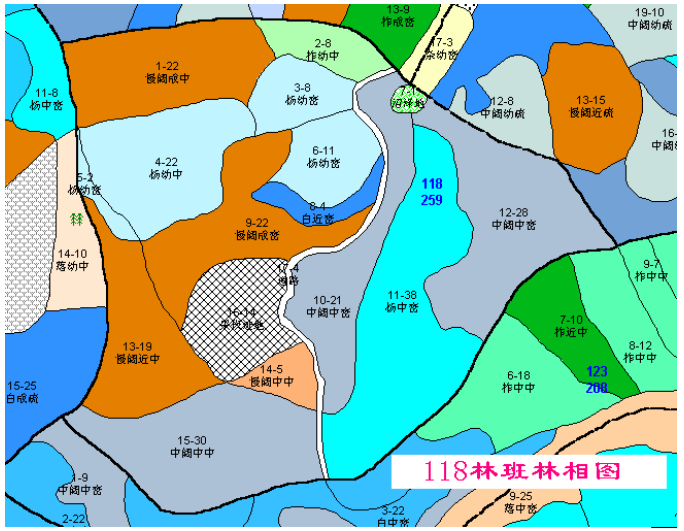




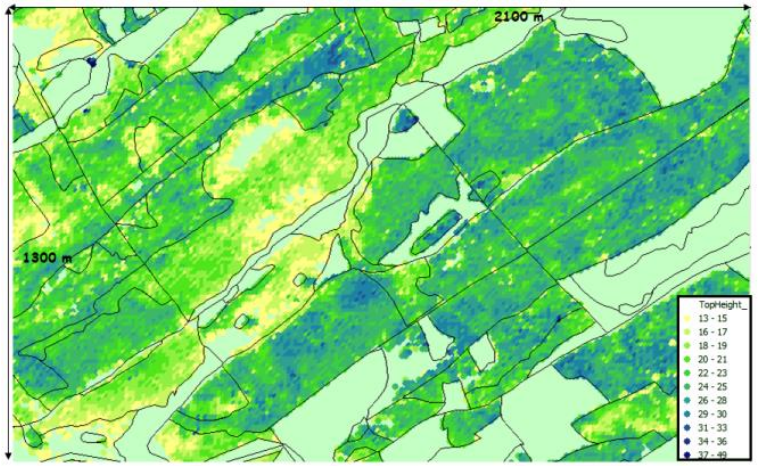


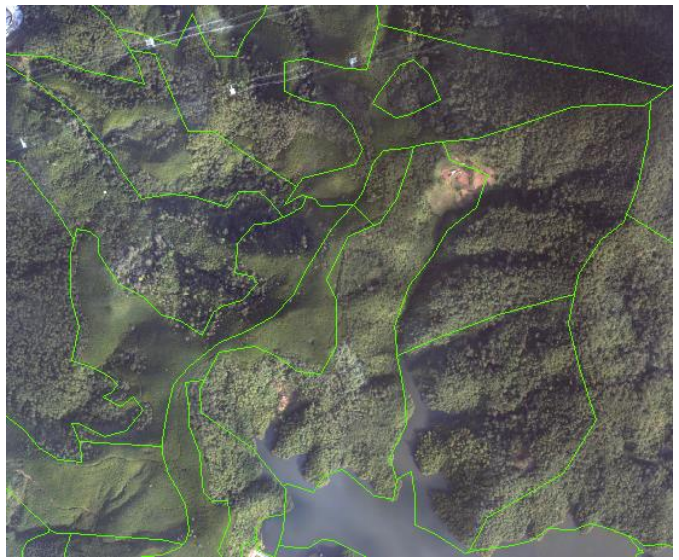
Forest Stand level:
ALS operational application Forest Management Inventory (FMI)

- **FMI** Objectives
  - **Forest management plan**
  - **Forest resources change**
  - **Forest management evaluation**
  - **Forest zonification**
  - **Logging quota determination**
  - **Ecological benefits compensation**



- Compartment and sub-compartment

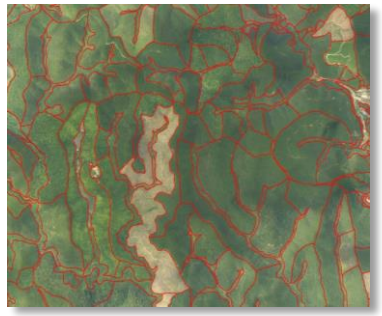




FMI using airborne remote sensing

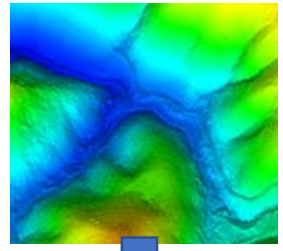
Airborne data collection

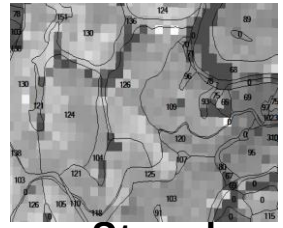
Aerial photo



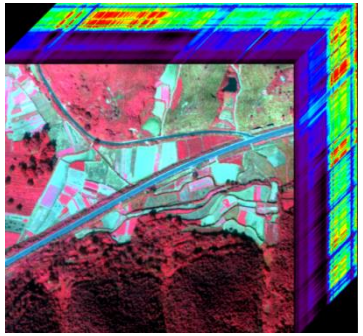
Stand boundary

Auxiliary info.

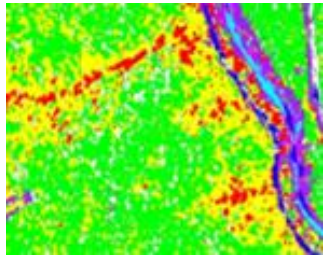




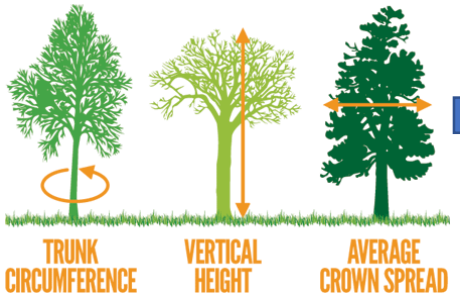
Stand parameter extraction



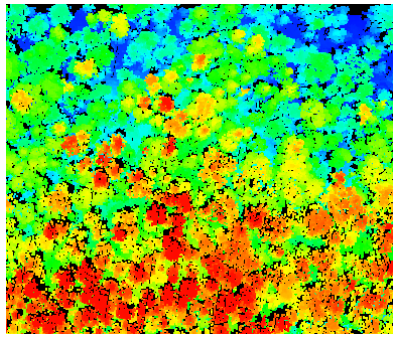
Airborne hyperspectral



Forest classification

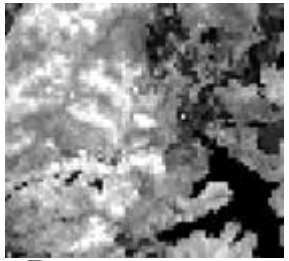


Field measurements



Airborne LiDAR

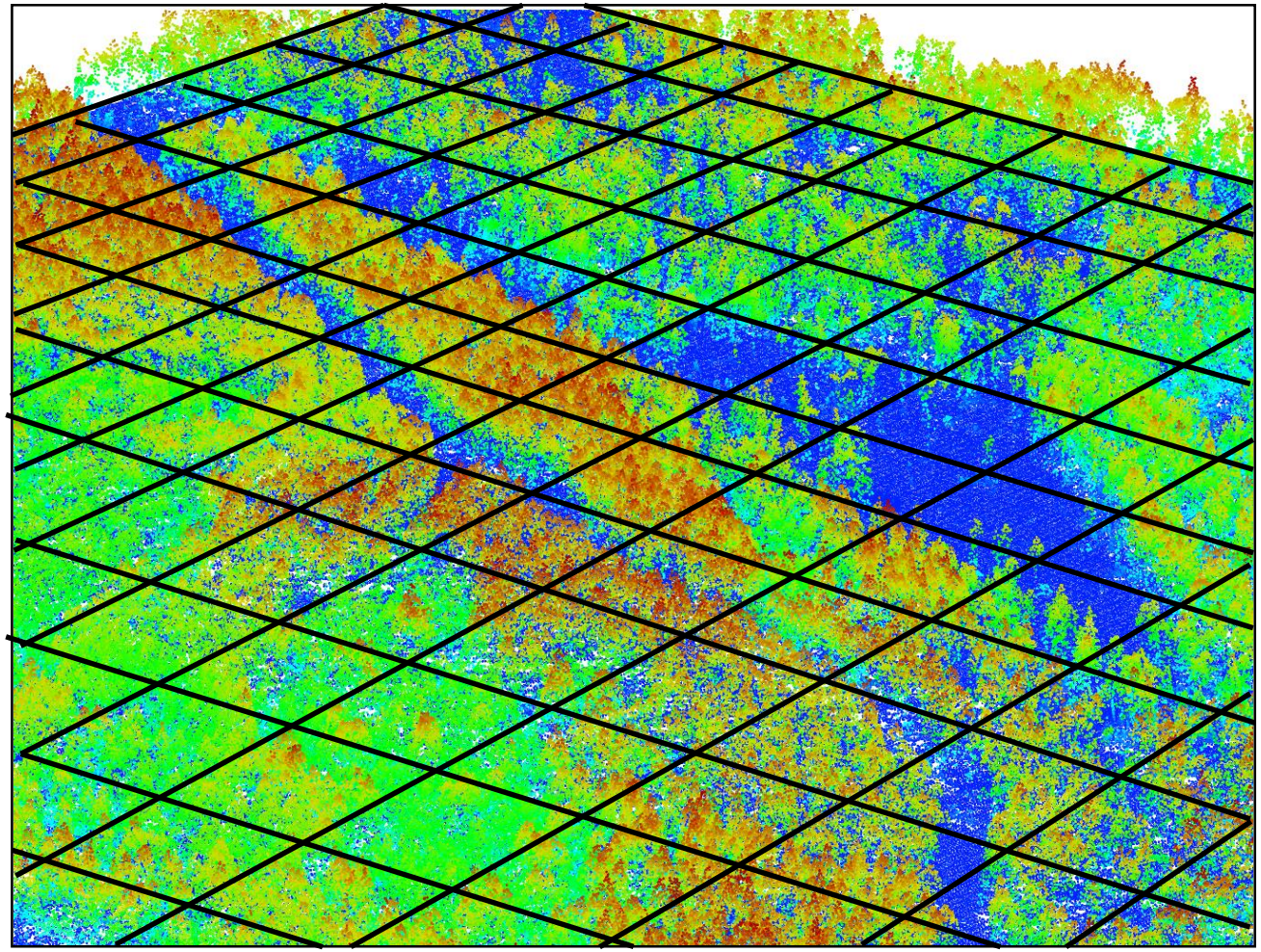
LiDAR metrics

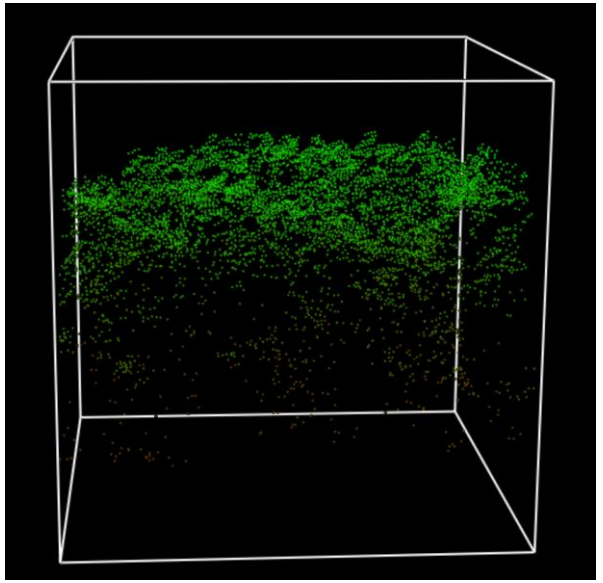


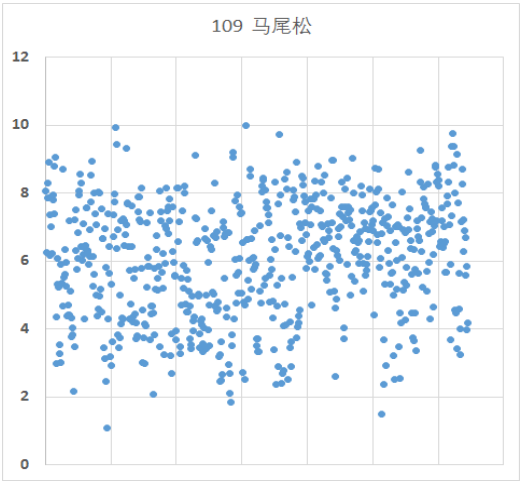
Parameters estimation using ALS

ALS Plot level indices calculation

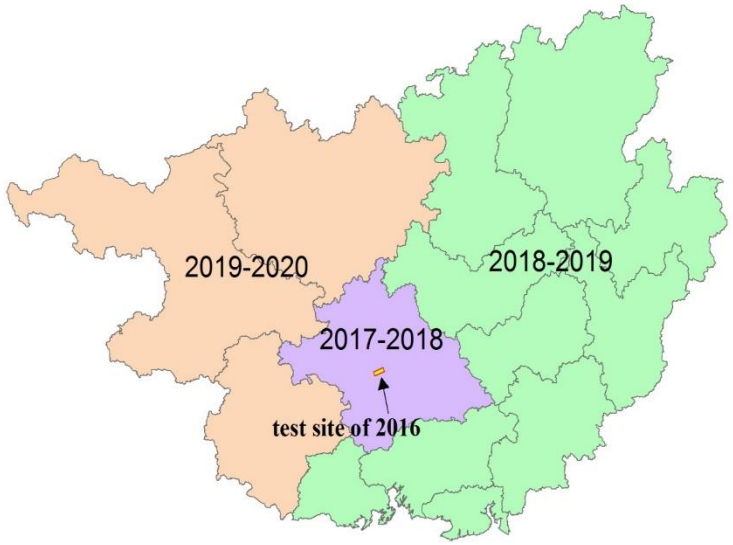
- **Extraction points for plots**
- **Calculate lidar indices for plots and cells**
- **Build parameter estimation modles**

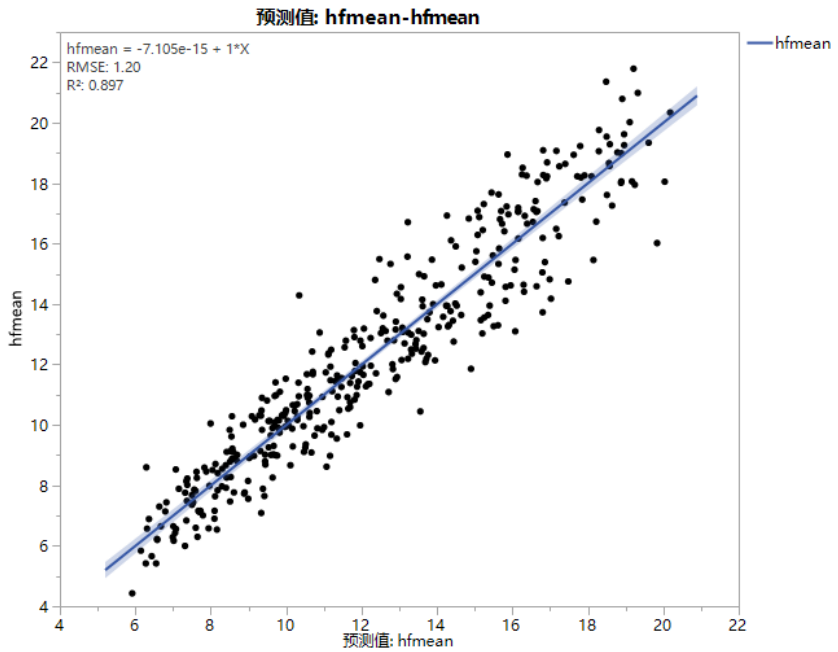


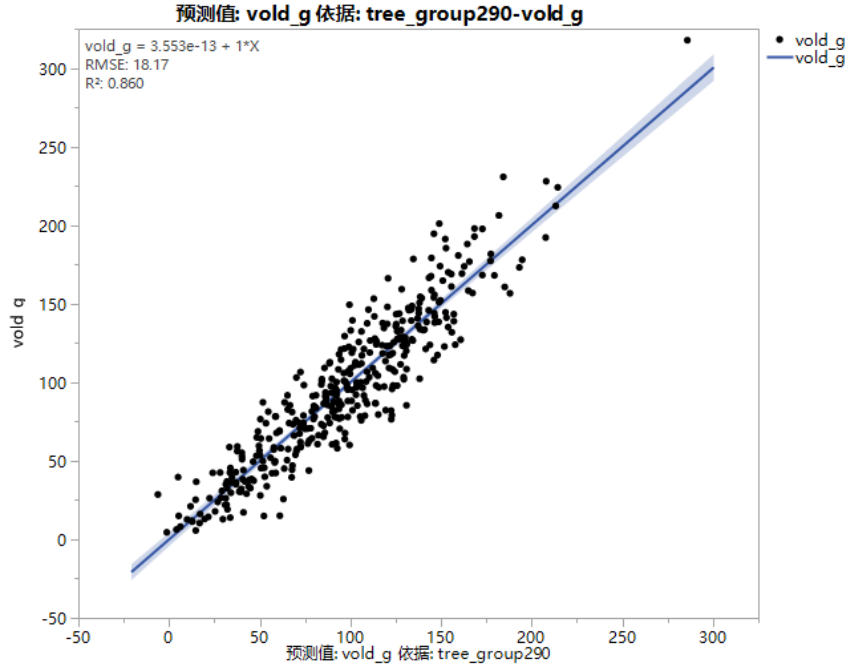




Forest height and volume density modeling results between Field Measurements and Lidar matrix

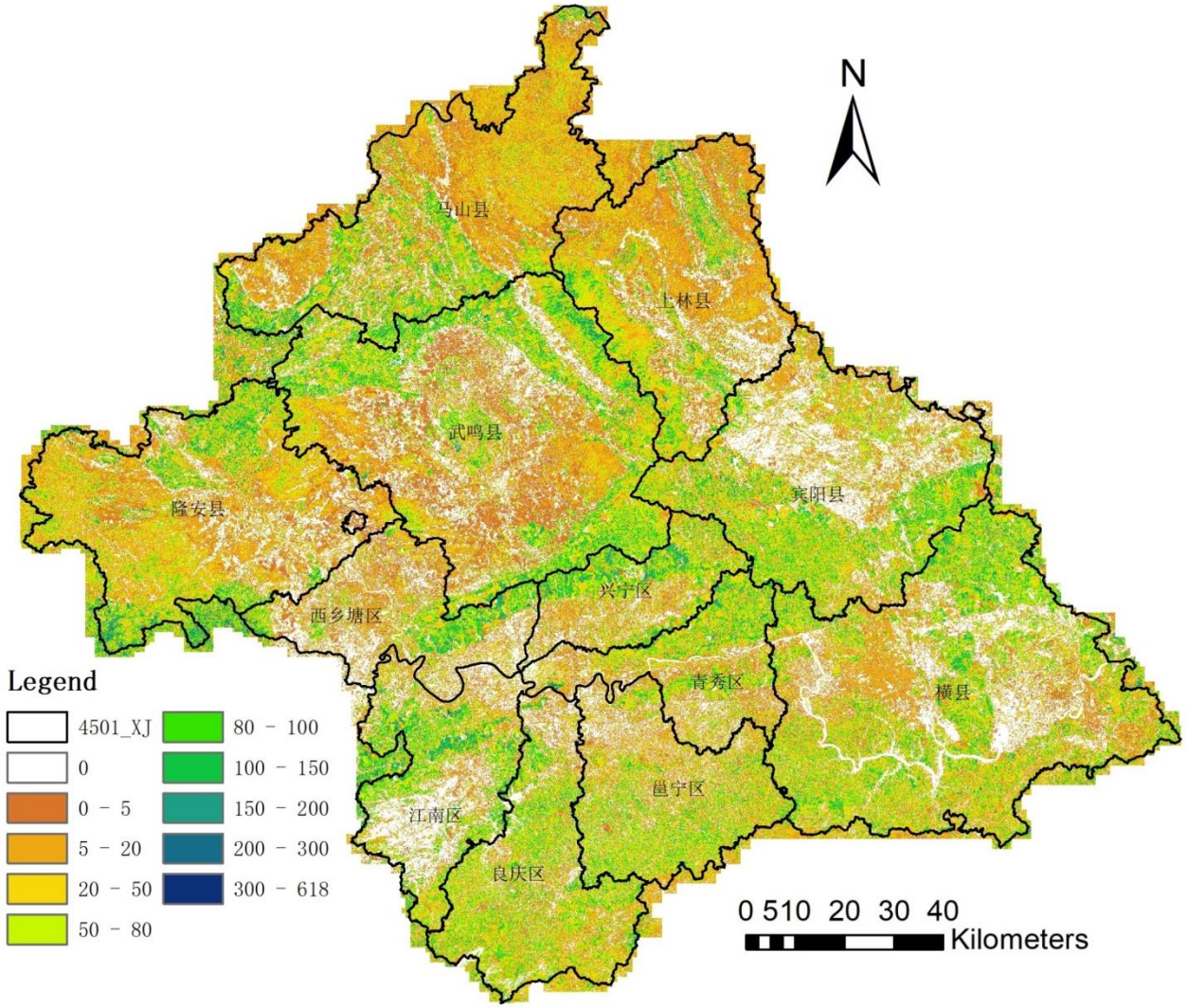


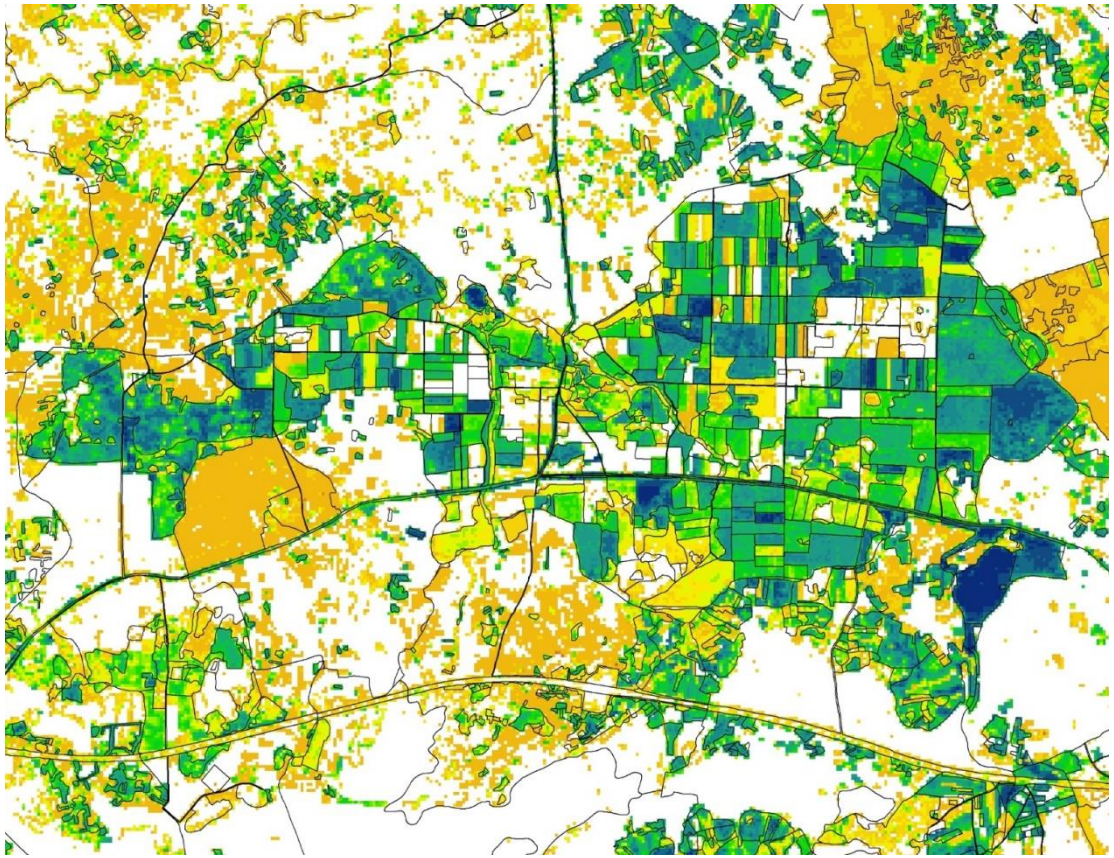




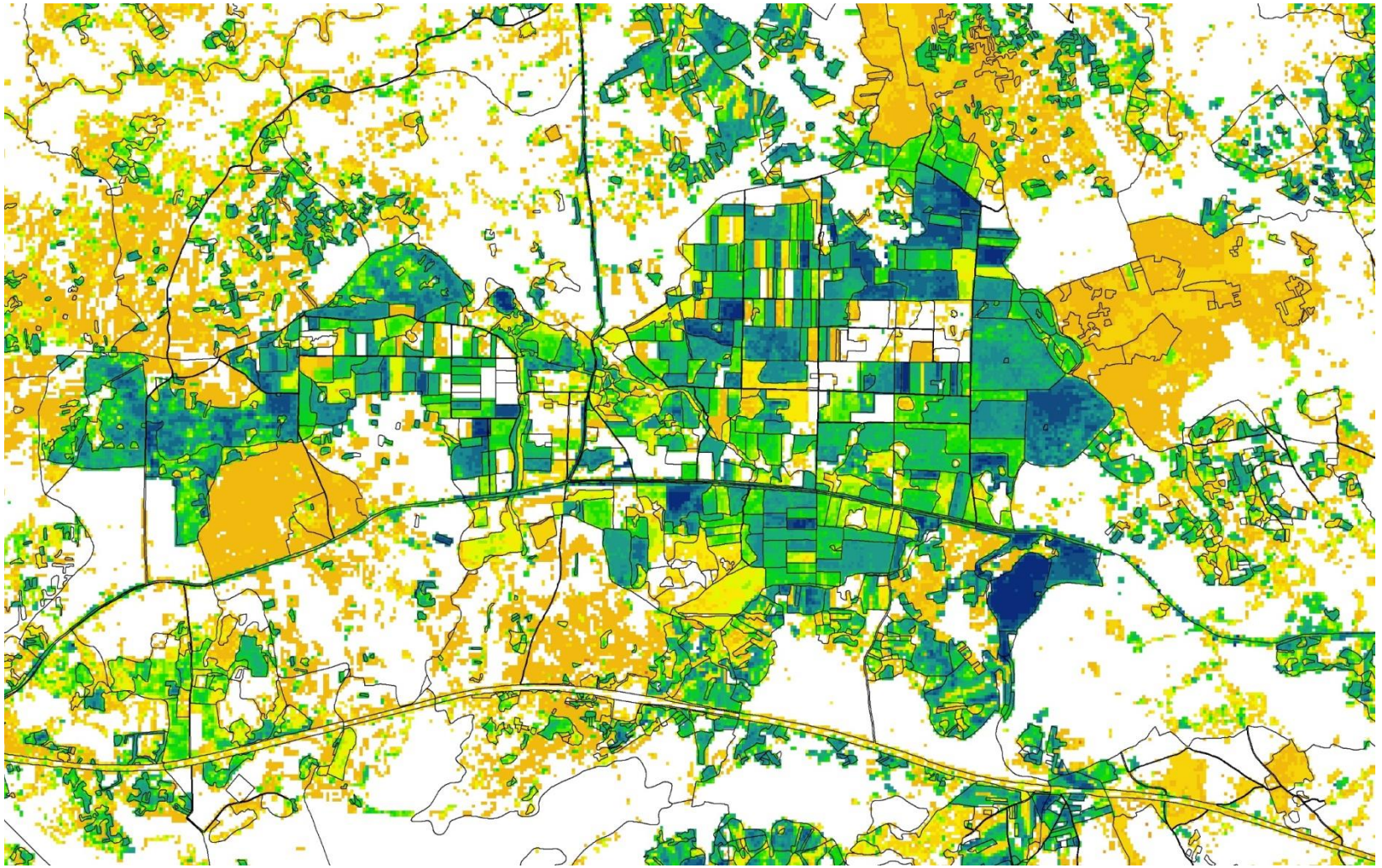
Forest type and variable	Plot no.	r^2	RMSE	SEE	MPE	MPSE
Chinese fir V*	89	0.80	21.1	20.93	4.89	16.51
Pine V	95	0.87	17.3	23.29	5.99	15.09
Eucalypts V	106	0.82	17.1	18.92	5.62	9.89
Other broadleaf V	98	0.80	19.0	21.35	10.09	32.07
Lorey's H	388	0.90	1.2	1.21	4.13	7.99

Estimated stand volume density in Guangxi, China

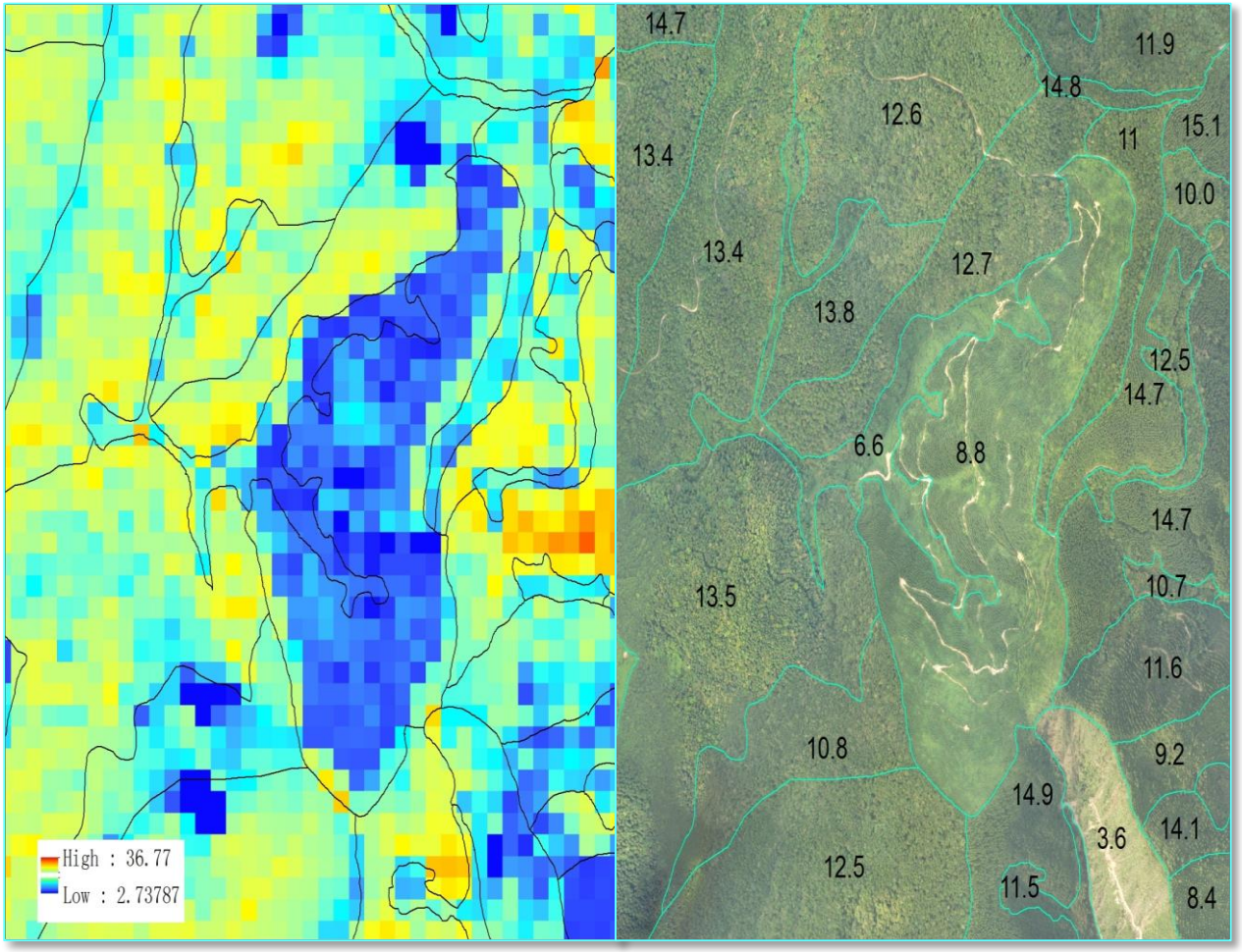


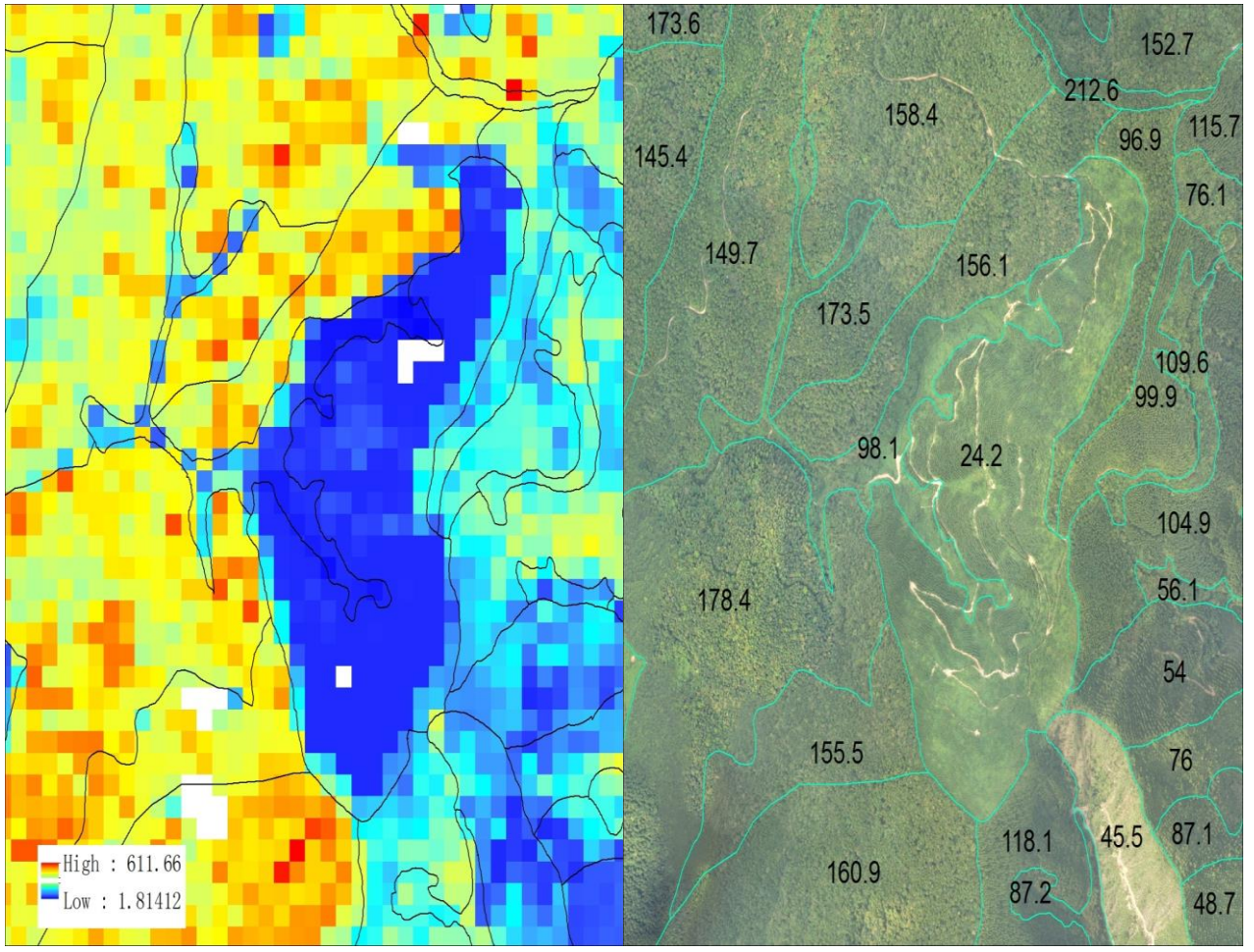


Estimated stand volume density



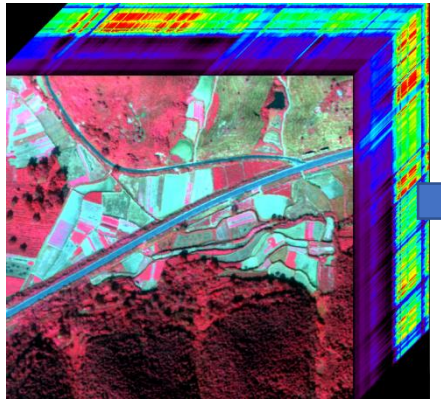
Mean height and volume extraction for forest stand



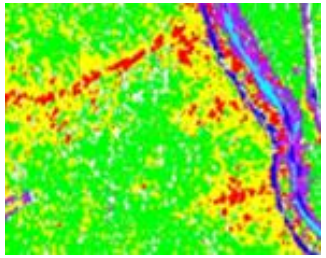


Regional AGB estimation using Field-Airborne-Spaceborne (FAS) data

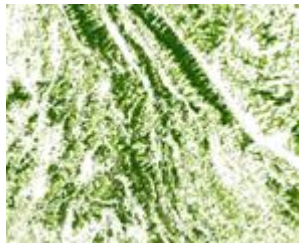
Airborne data collection



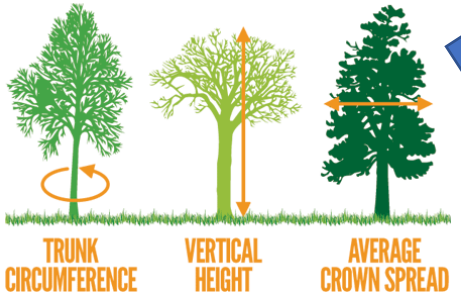
Airborne hyperspectral



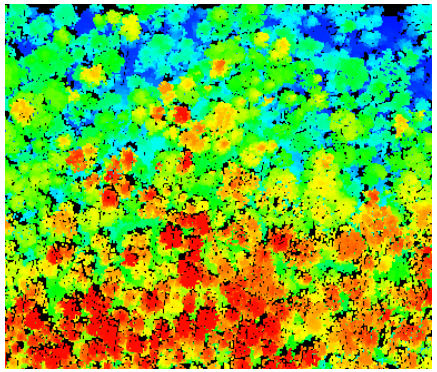
Forest classification



Modelling with satellite data

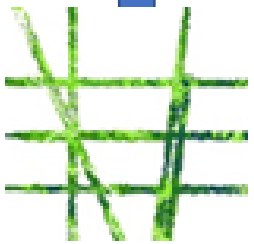


Field measurements



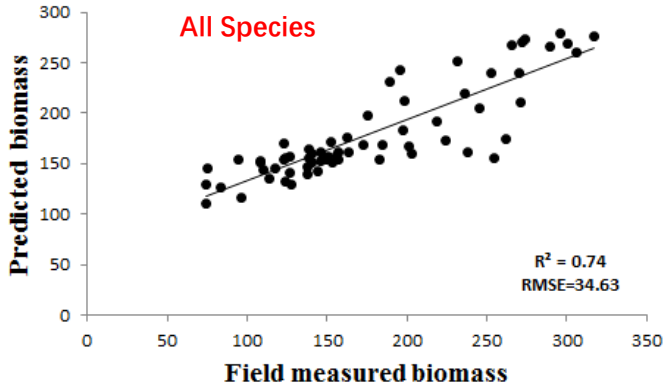
Airborne LiDAR

LiDAR metrics

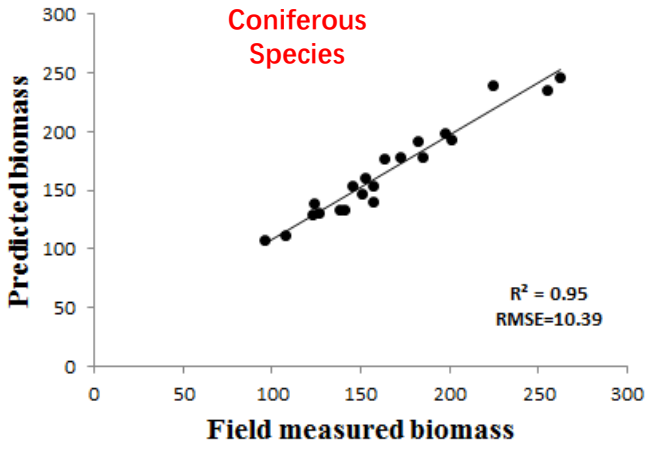


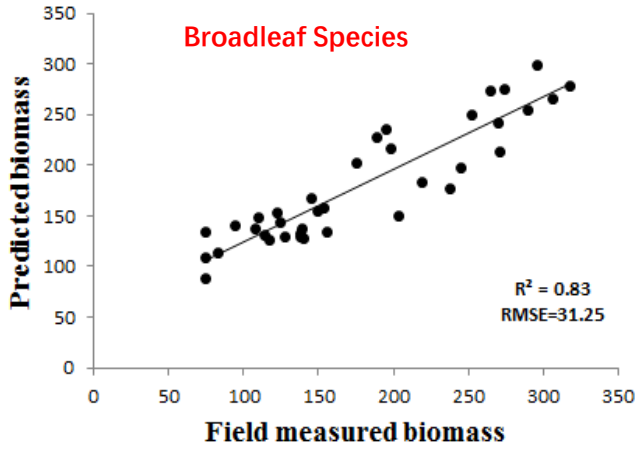
Biomass estimation over airborne transects

Forest biomass estimation for each dominate forest type using airborne waveform LiDAR data:

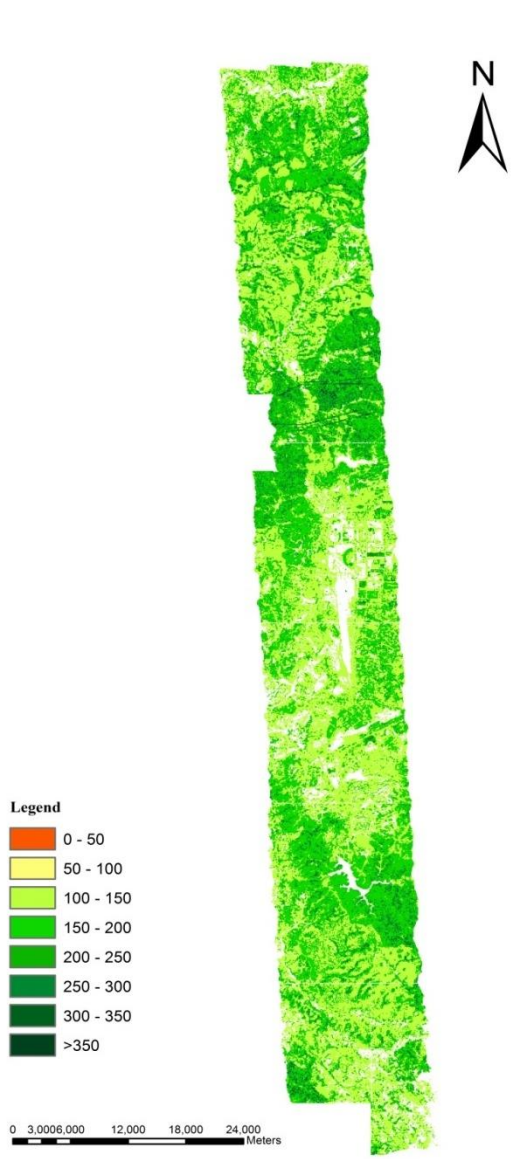


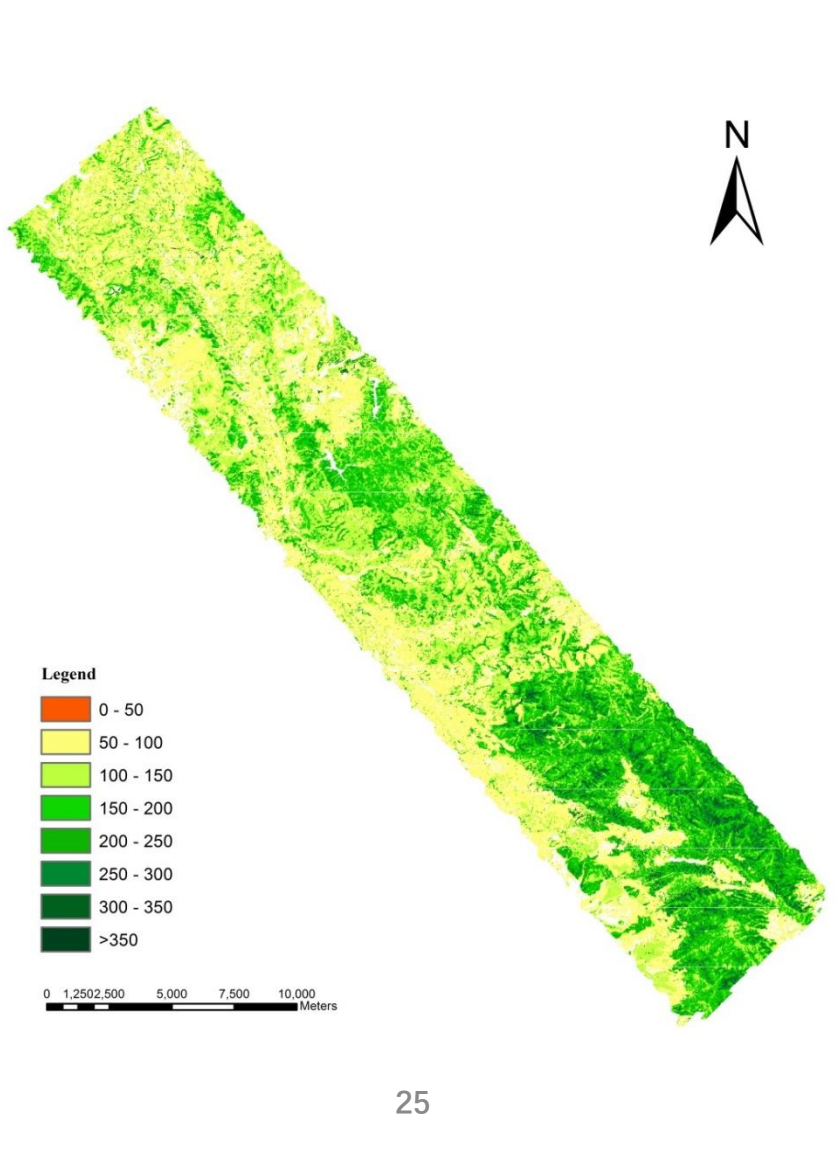
The R^2 improved 0.09 and 0.21 for broadleaf and coniferous species separately.

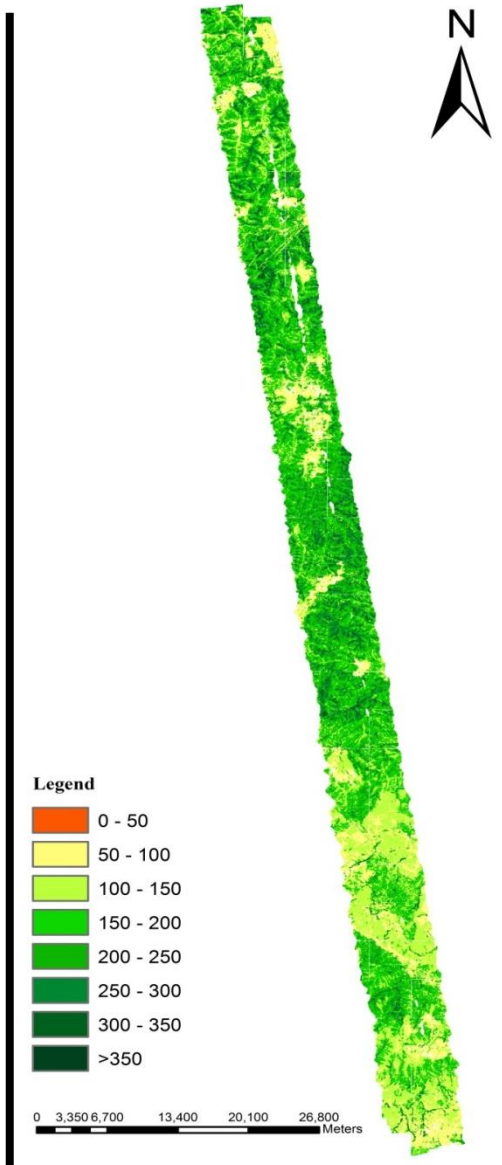




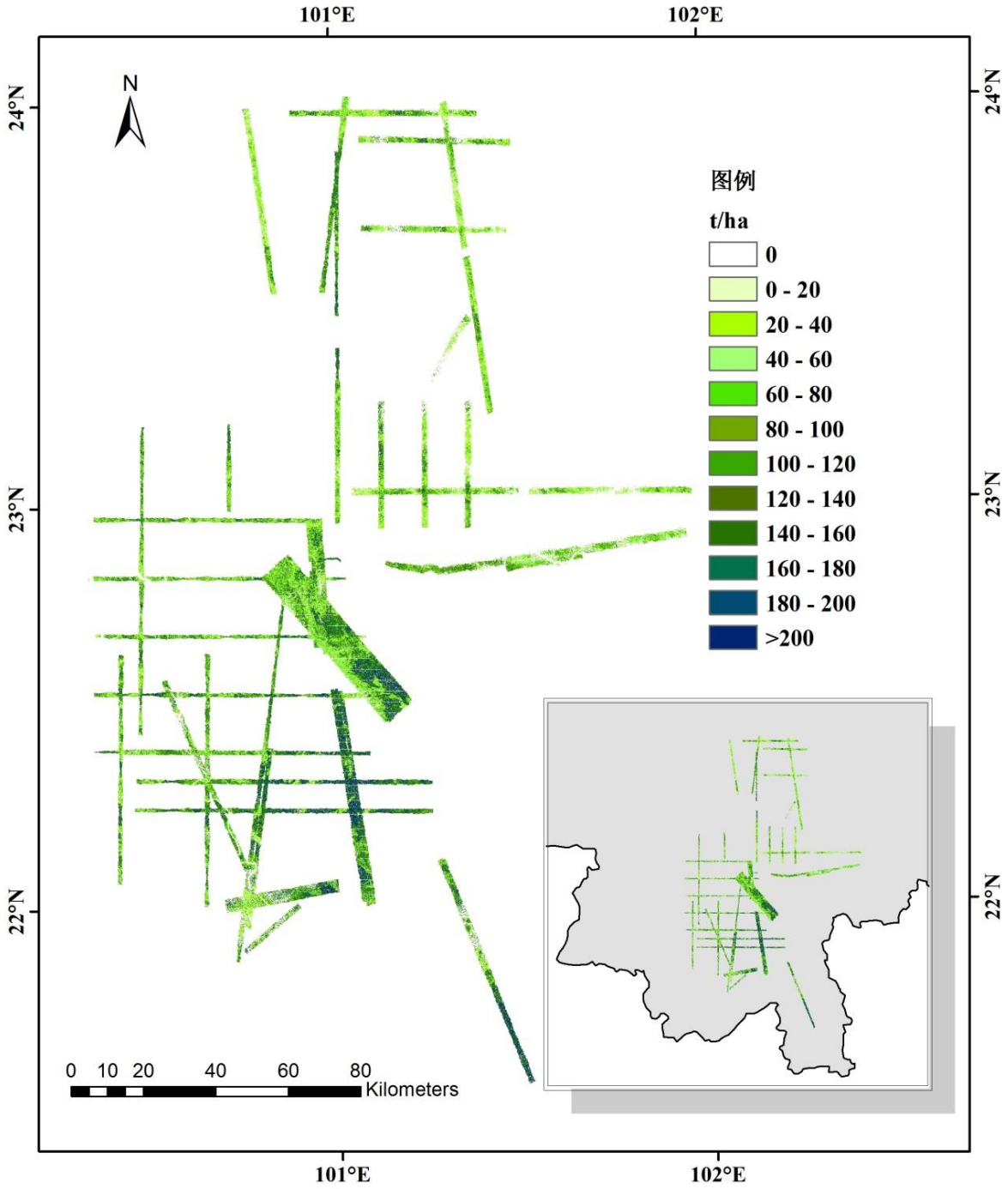
Forest AGB mapping along ALS transects



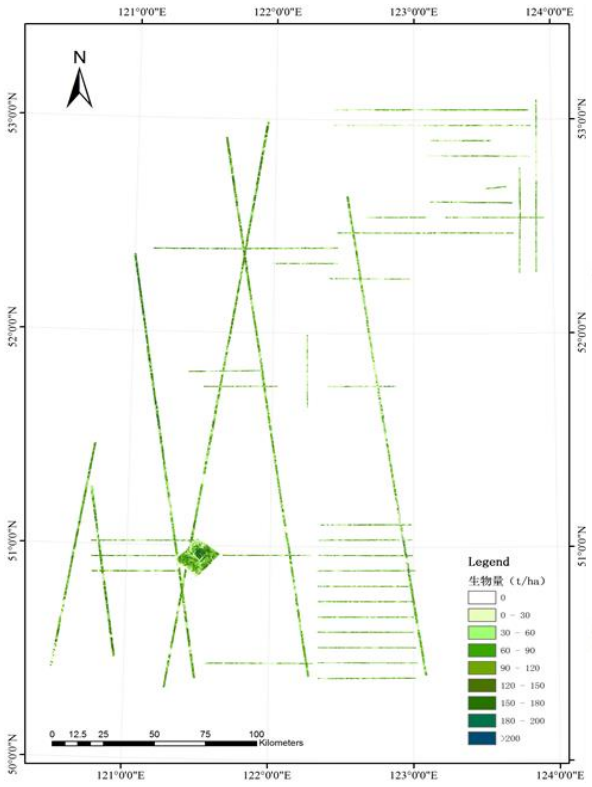




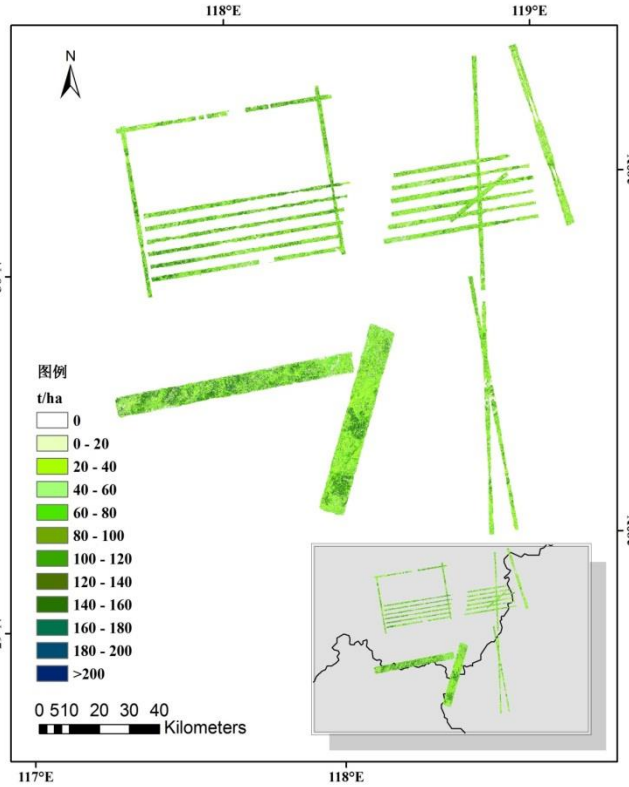
Biomass estimation for ALS transects in Yunnan Province, SW of China



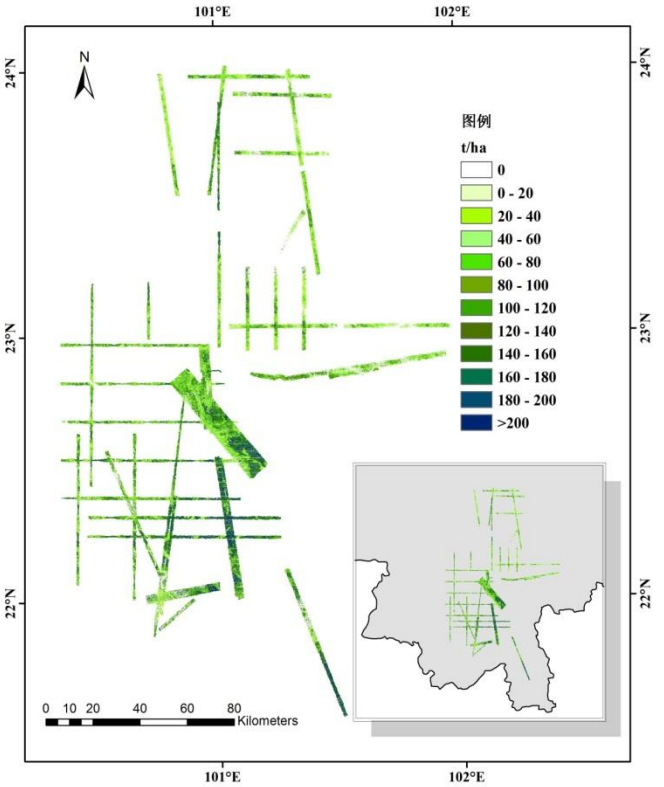
Biomass estimation for ALS transects in China typical forests



Northeast
temperate forest

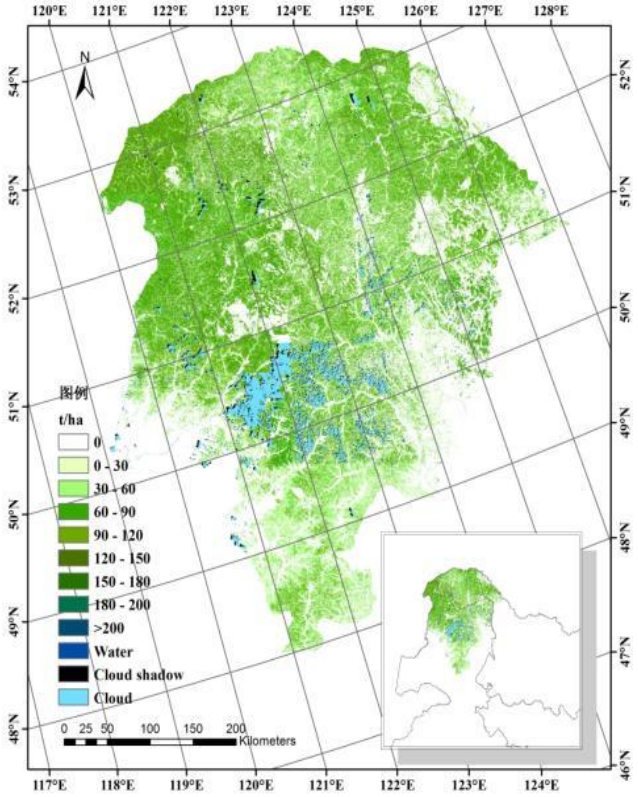


Central
Sub-tropical forest

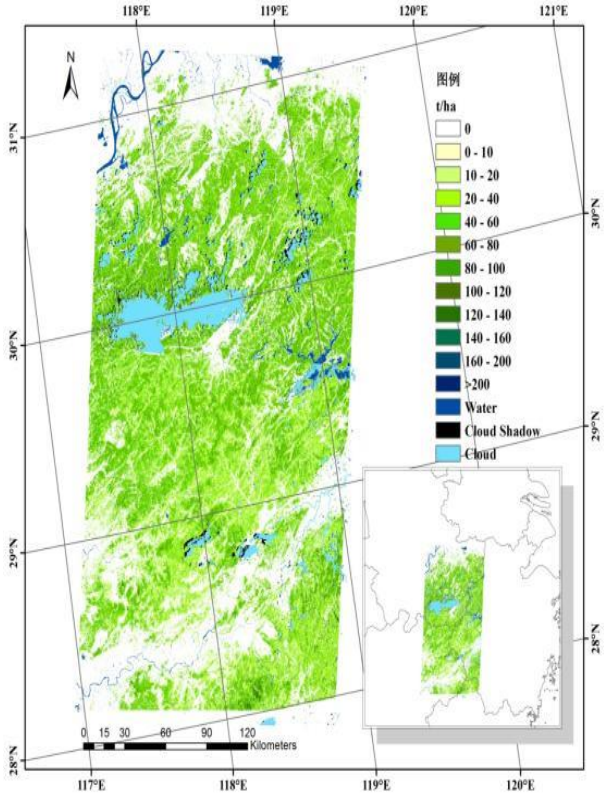


Southwest
Sub- / tropical forest

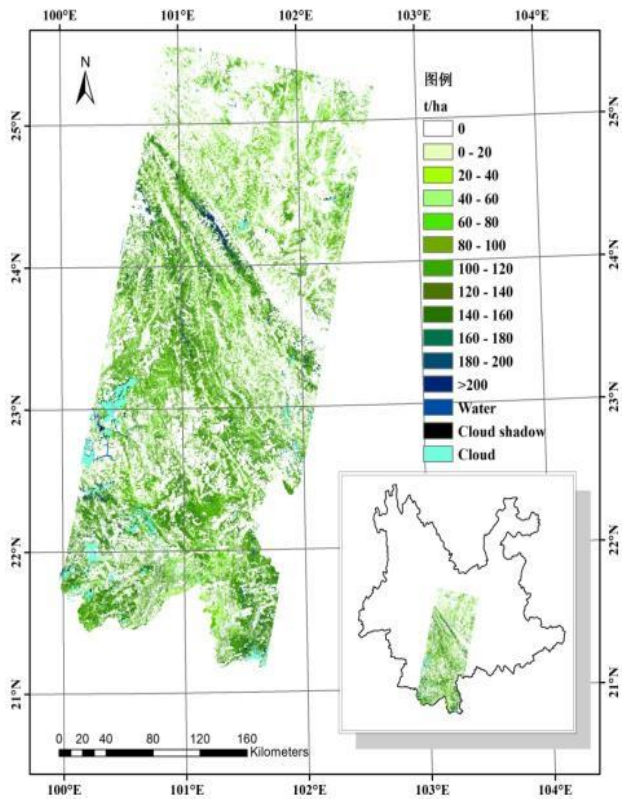
Biomass estimation in China typical forests



Northeast
temperate forest



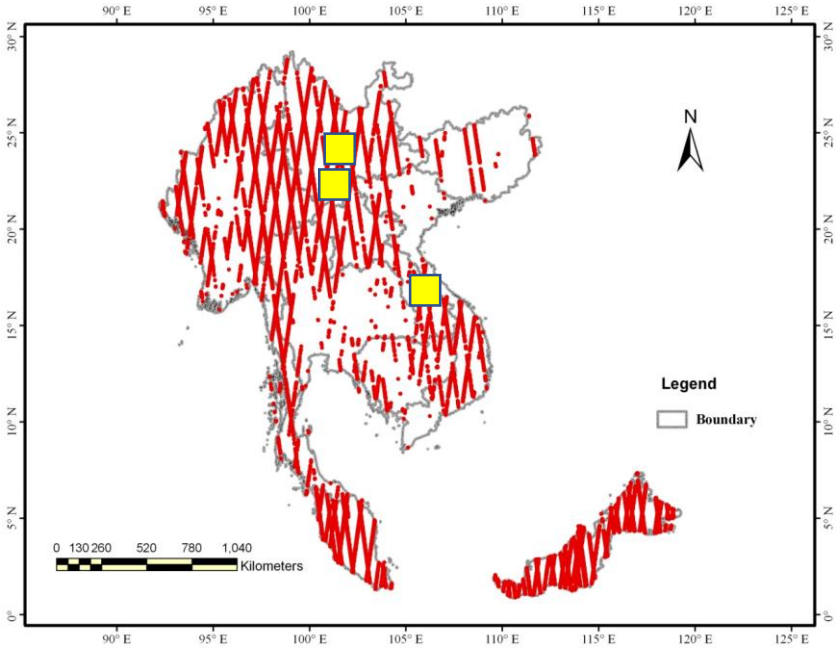
Central
Sub-tropical forest



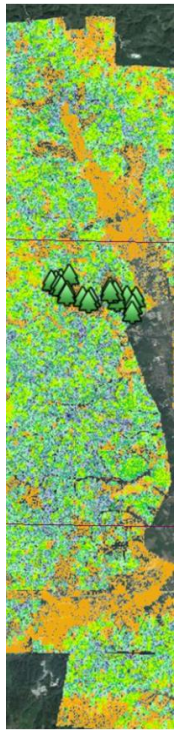
Southwest
Sub- / tropical forest

Pang et al., 2013 & 2016

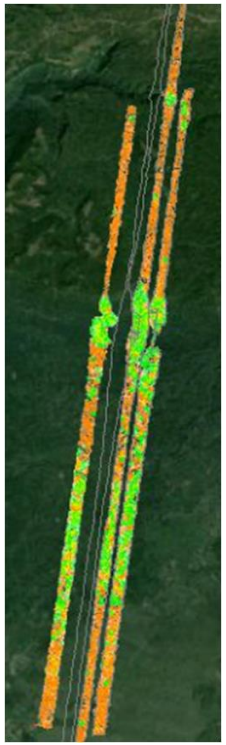
Airborne Waveform Lidar Data Collection along ICESat GLAS Orbits



Kunming, China 2007

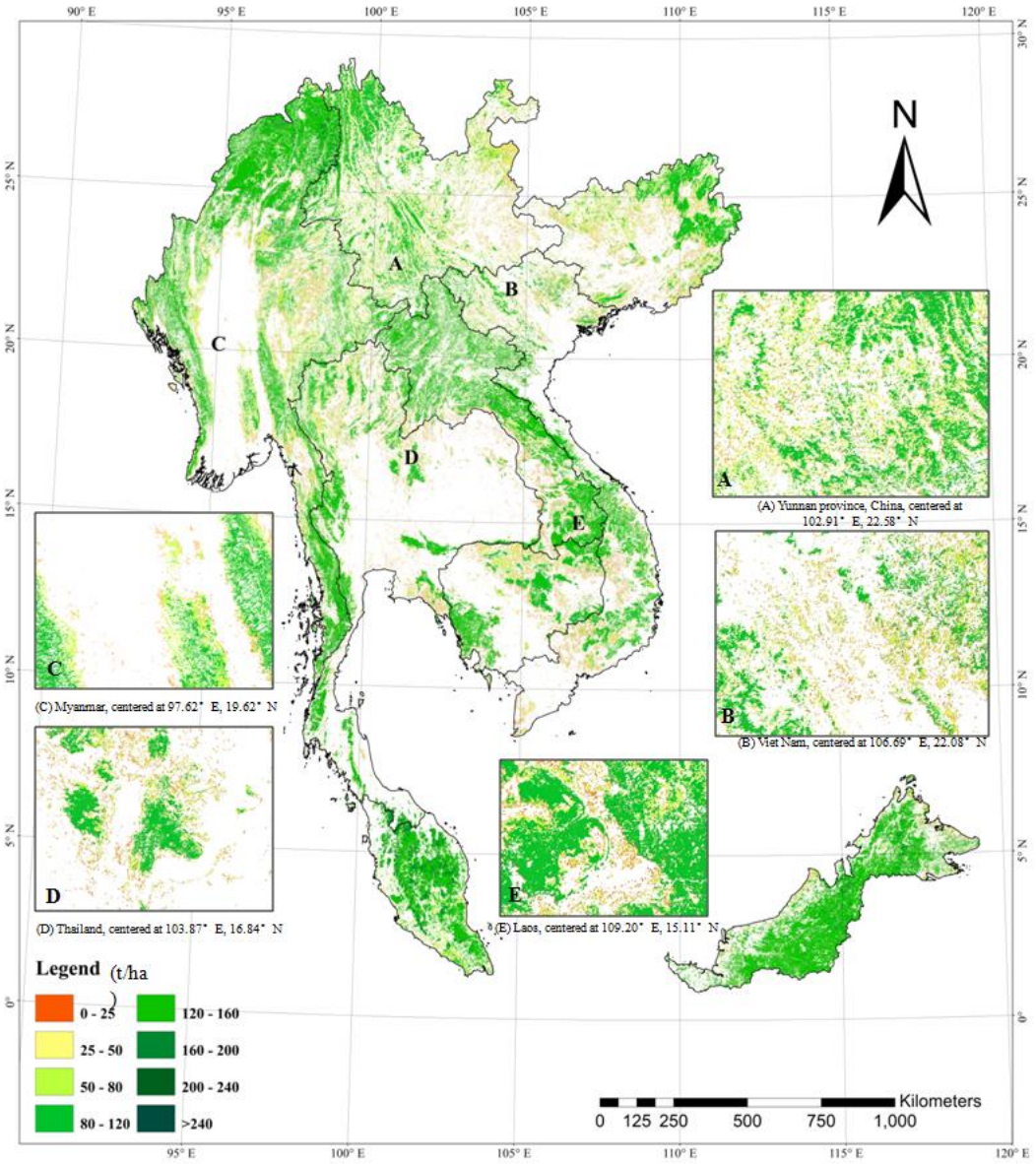


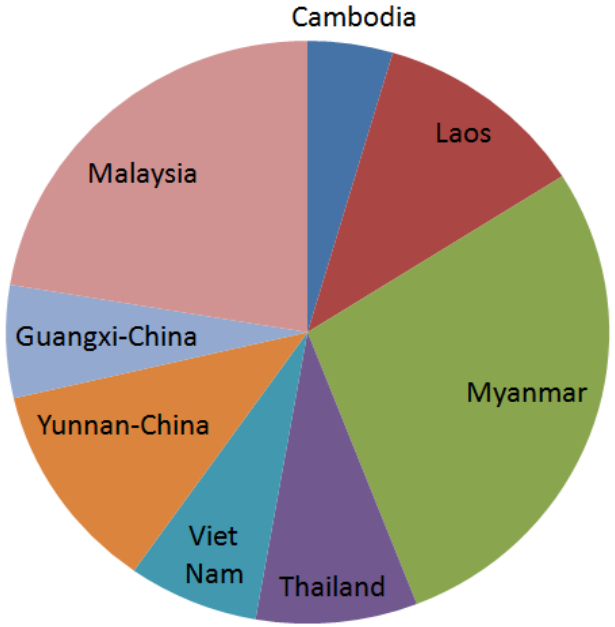
Jinghong, China, 2009

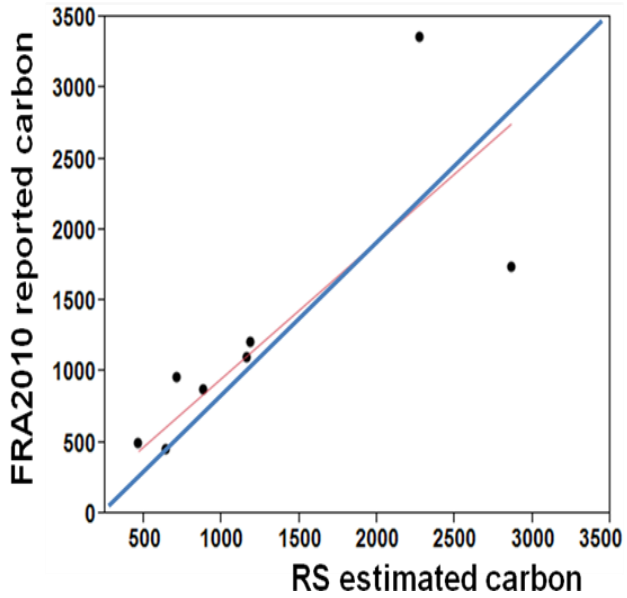


Chambas, Laos, 2012

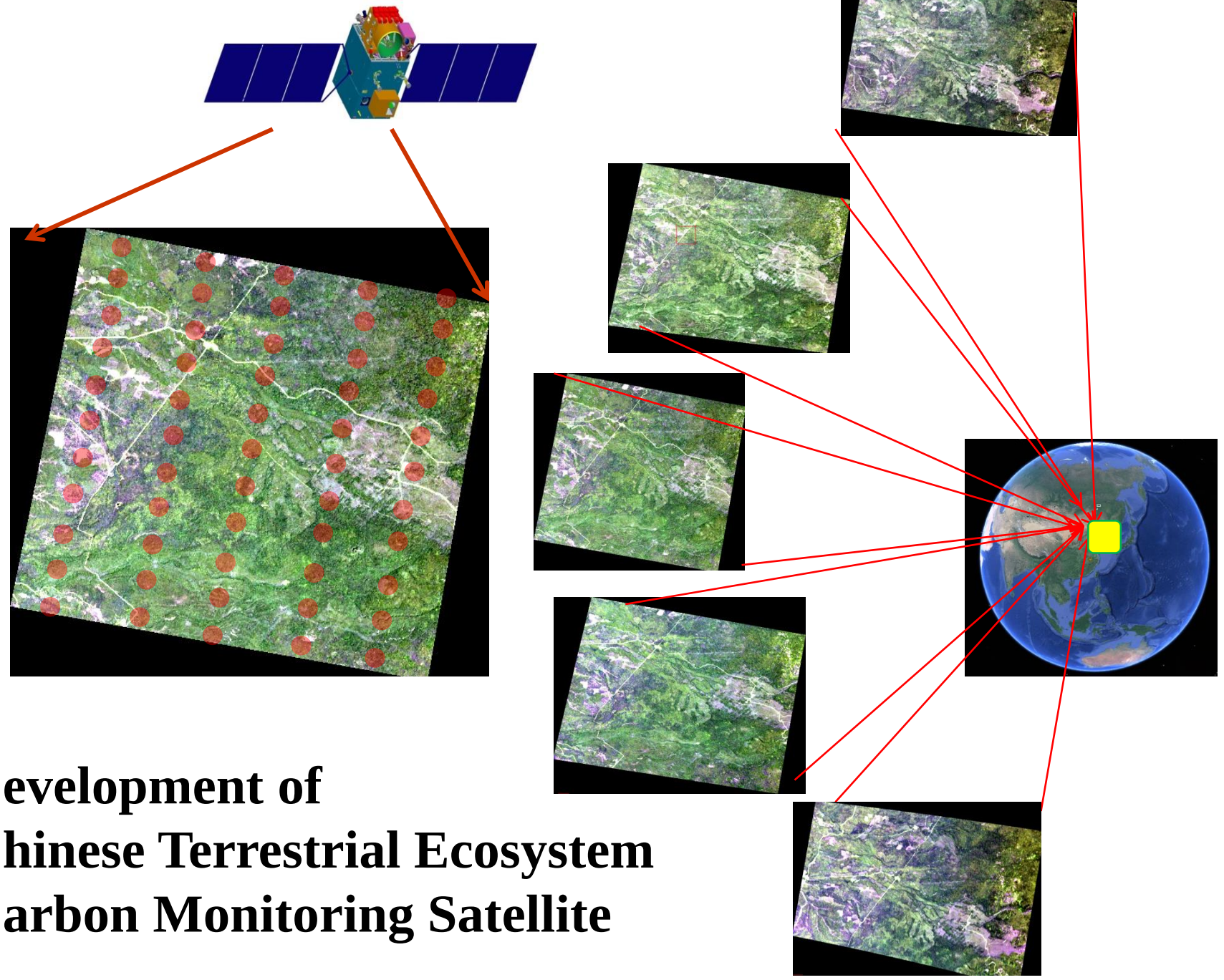
Forest Carbon estimation in GMS & Malaysia (2005)





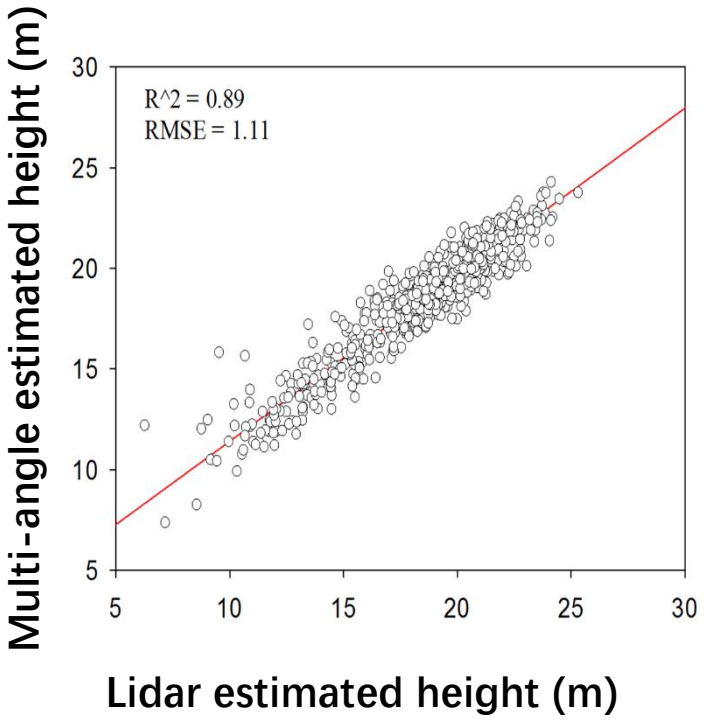


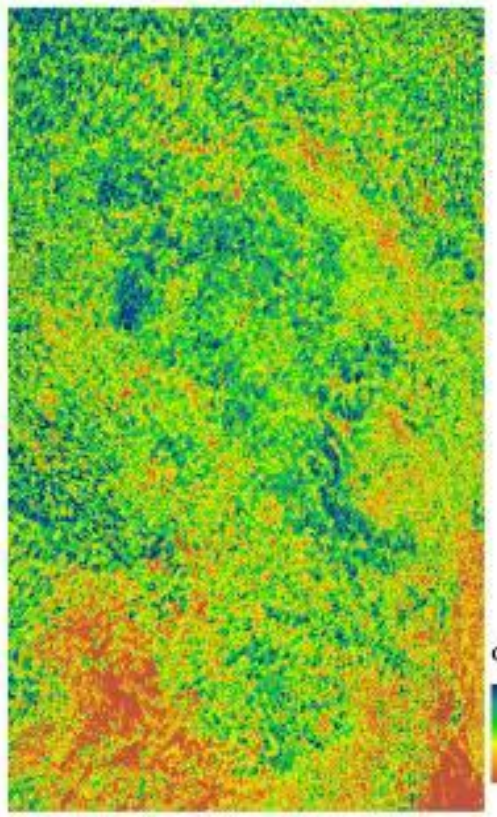
Pang et al., 2011



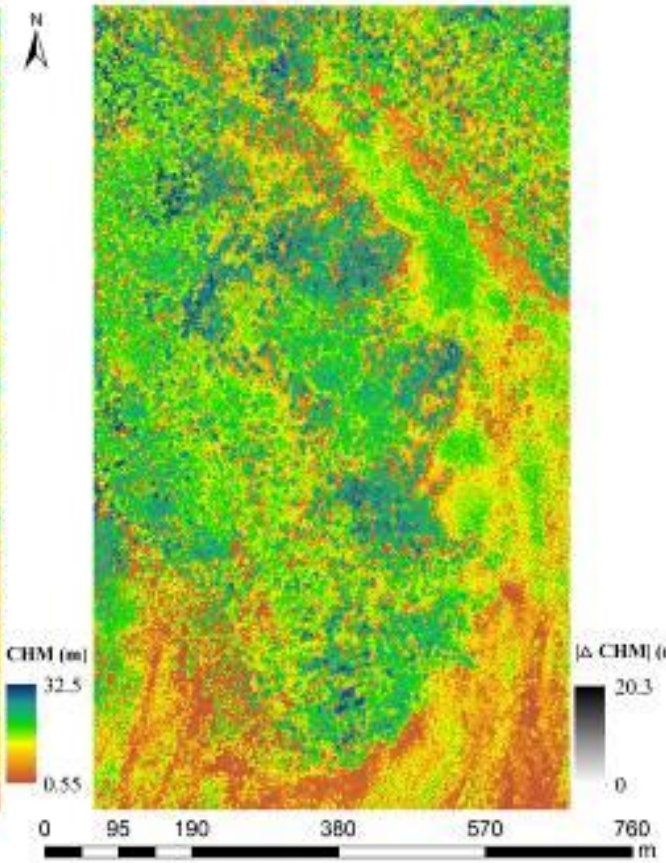
Development of Chinese Terrestrial Ecosystem Carbon Monitoring Satellite

Forest height estimation using simulated angular optical data

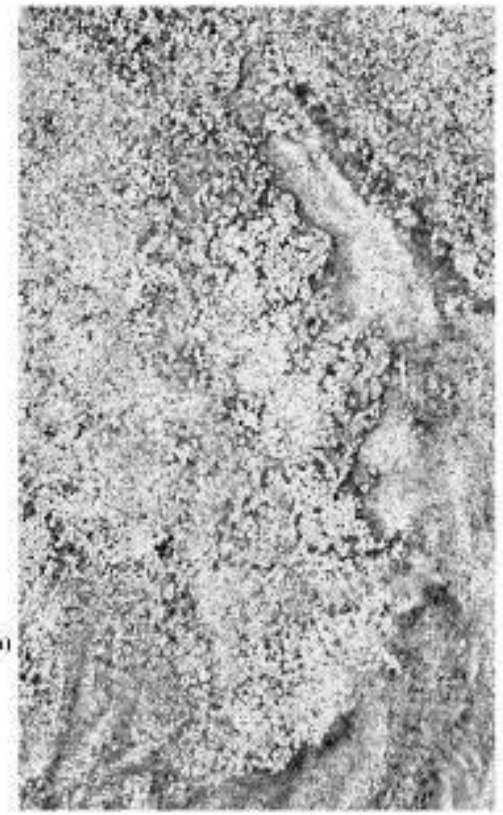




Forest height from airborne multi-angle data



Lidar CHM



Height difference

Pang et al., 2016

Conclusion

- Lidar remote sensing technology brings a good solution for forest parameters measurement and carbon estimation at tree, stand, and regional levels.
- Forest biomass was estimated by FAS comprehensive observation, that is combining field measurements from forest inventory system, airborne LiDAR, and spaceborne remote sensing data for estimation purpose, was very effective for regional areas.
- The airborne Lidar is a very efficient way for provincial forest management inventory.
- As several spaceborne Lidar are working now, it is a good period to update regional forest carbon product.