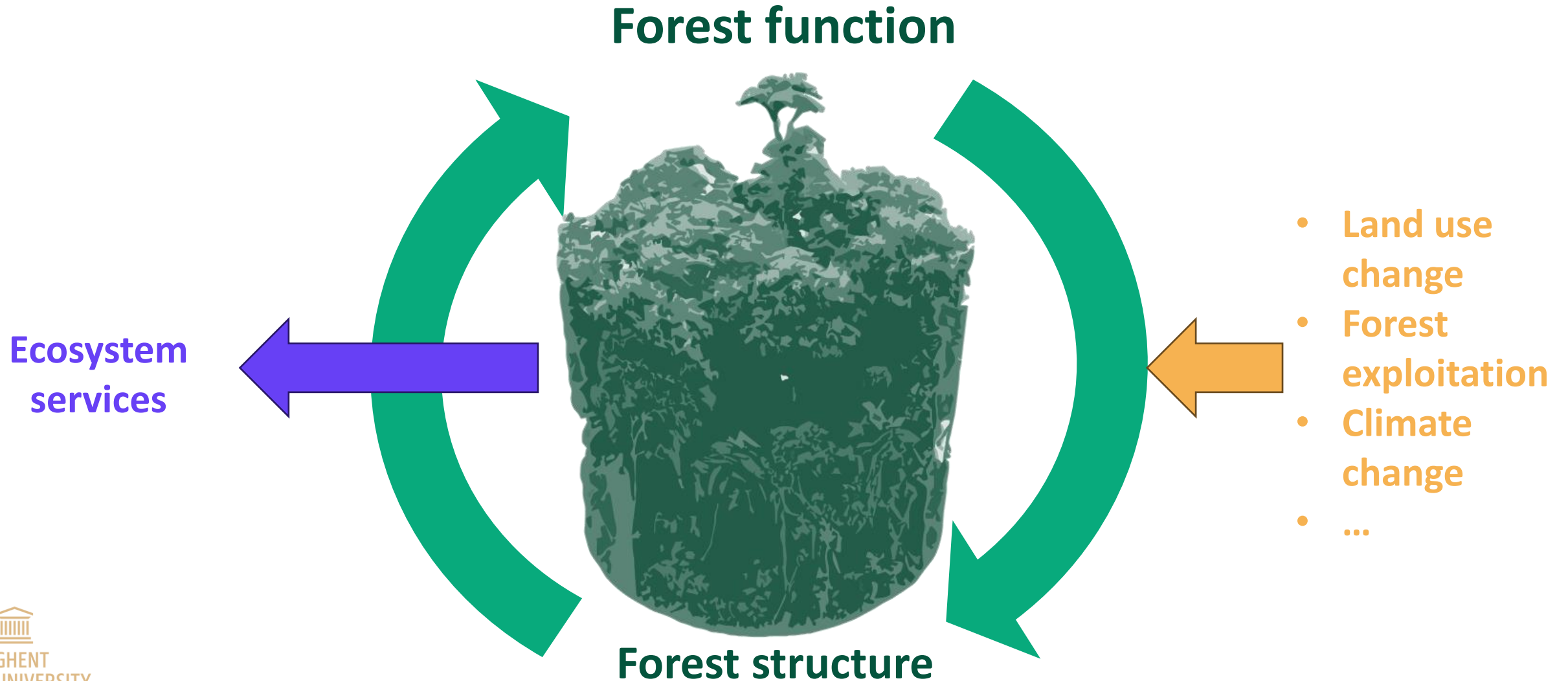


Terrestrial Laser Scanning for Tree Structure Quantification in Tropical Rainforests

Louise Terryn, Kim Calders, Hans Verbeeck



INTRODUCTION



INTRODUCTION

Individual tree structure

→ Structural metrics

- Stem diameter
- Tree height
- ...

→ Traditional field census methods

- Difficulties in tropical rainforests (buttresses, closed canopy)
- High variance and biases



Source: Blundo et al., 2021



Source: Kim Calders

INTRODUCTION

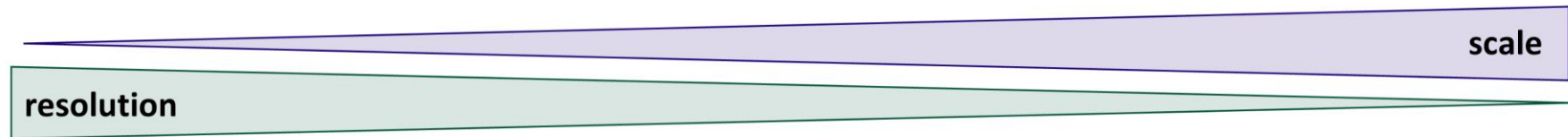
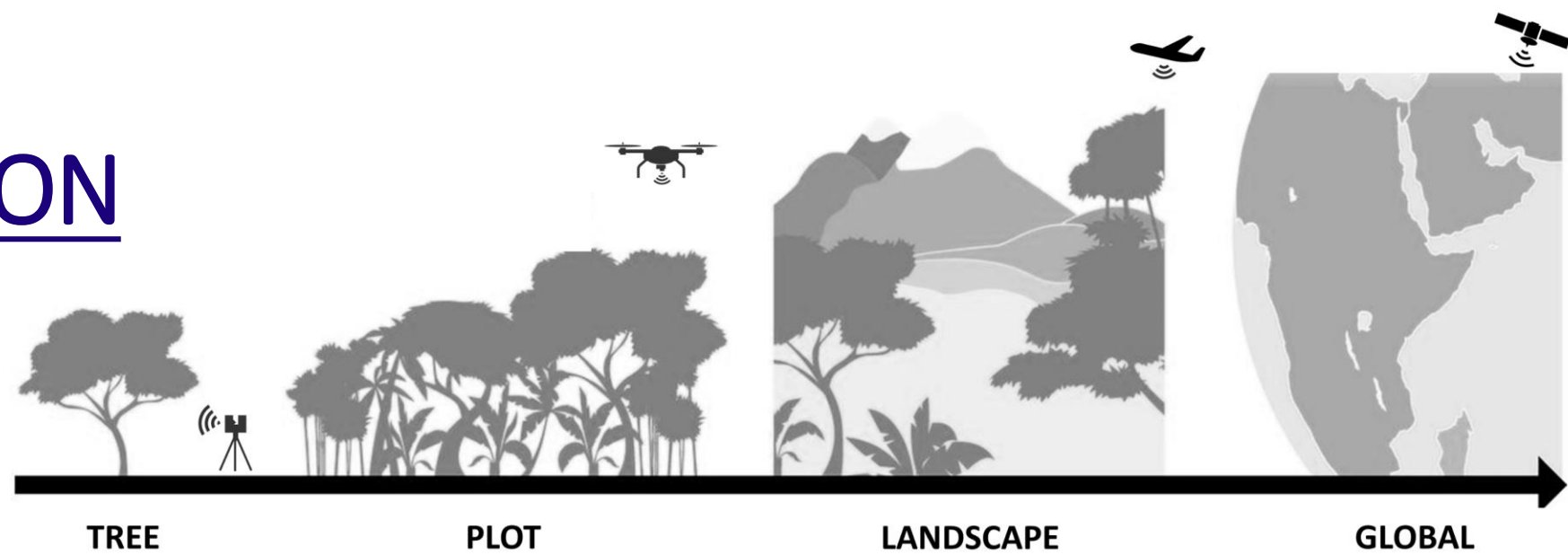
Laser scanning
(lidar)



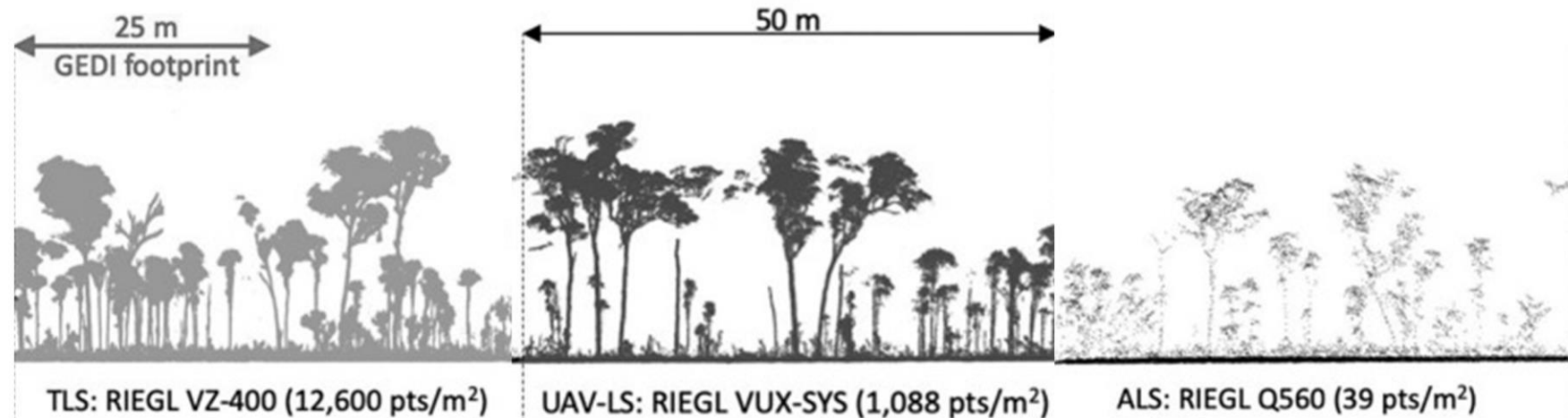
INTRODUCTION

Laser scanning (lidar)

- Terrestrial laser scanning (TLS)
- UAV laser scanning (UAV-LS)
- Airborne laser scanning (ALS)
- ...



(a)



(b) Source: figure adapted from Calders et al., 2020

INTRODUCTION

Occlusion

→ Accuracy of structural metrics

Terrestrial laser scanning (TLS)



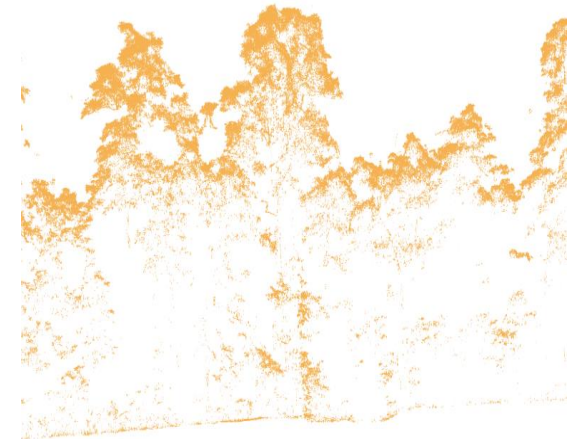
UAV laser scanning (UAV-LS)



occlusion



occlusion



STUDY 1: OBJECTIVE

Quantify the accuracy of
TLS and UAV-LS structural
measurements in tropical
rainforests

Terrestrial laser scanning (TLS)



UAV laser scanning (UAV-LS)



STUDY 1: OBJECTIVE

Quantify the accuracy of
TLS and UAV-LS structural
measurements in tropical
rainforests

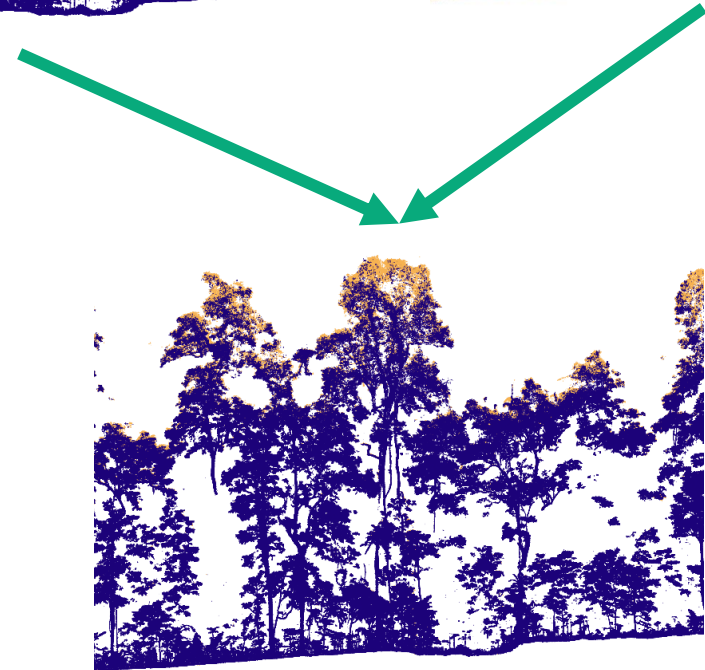


Fusion
TLS + UAV-LS
=
reference

Terrestrial laser scanning (TLS)

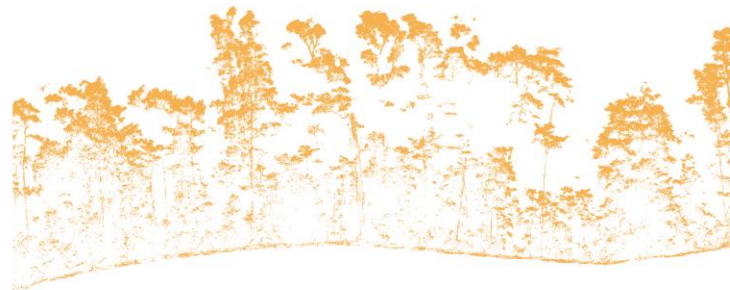
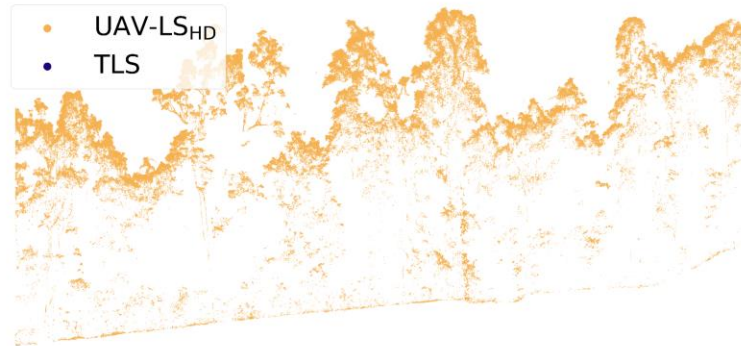


UAV laser scanning (UAV-LS)



STUDY 1: METHODS

UAV-LS



TLS



UAV-LS +
TLS



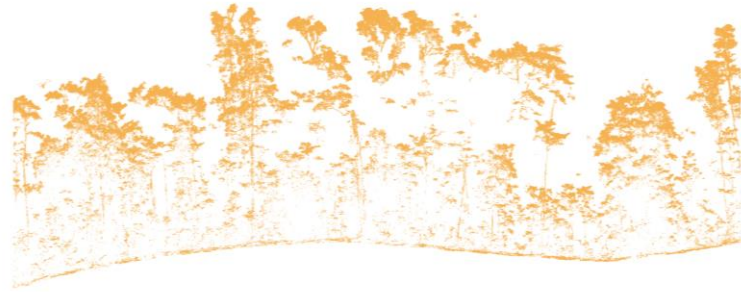
Oliver Creek

Robson Creek

25 m

STUDY 1: METHODS

UAV-LS



89 trees



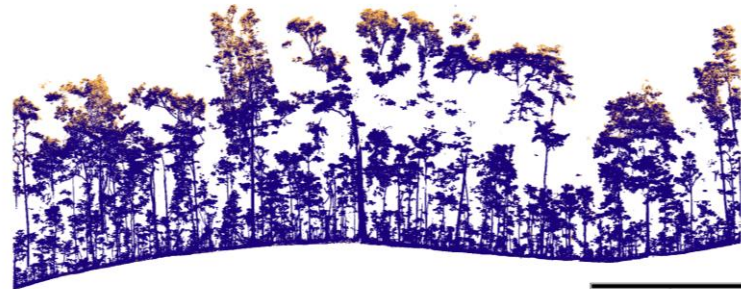
TLS



89 trees



UAV-LS +
TLS



89 trees

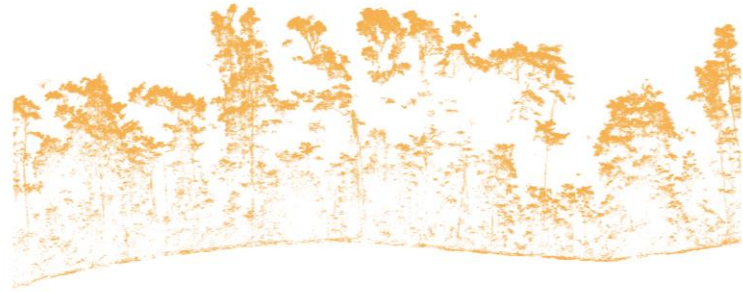


Robson Creek

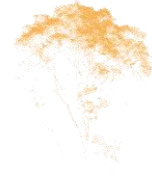
25 m

STUDY 1: METHODS

UAV-LS

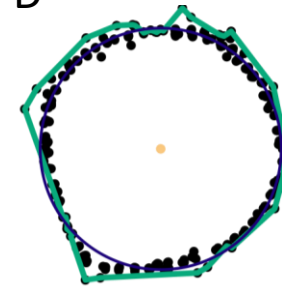


89 trees



- Stem diameter (D)
- Tree height (H)
- Crown projection area (CPA)
- Crown volume (CV)

D



- concave hull
- estimated center
- fitted circle
- points at breast height

TLS



CPA

CV



- concave hull
- points

UAV-LS +
TLS

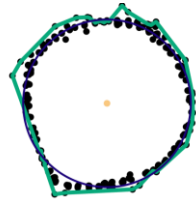


Robson Creek

25 m

STUDY 1: RESULTS

Average D = 45 cm



Average H = 27 m



Average CPA = 67 m²



Average CPA = 319 m³



	Stem diameter	Tree height	Crown projection area	Crown volume
Reference	Traditional field measurements	Measurement from the fused tree point cloud		
TLS	RMSE = 5 cm	RMSE = 0.30 m	RMSE = 3.06 m ²	RMSE = 29.63 m ³
UAV-LS	Not possible for 73% of trees	RMSE = 0.31 m	RMSE = 5.01 m ²	RMSE = 27.23 m ³

Mean difference < 1 %

Mean difference < 10 %



STUDY 2: OBJECTIVE

Quantify the error on H:D
models based on
traditional field census in
tropical rainforests

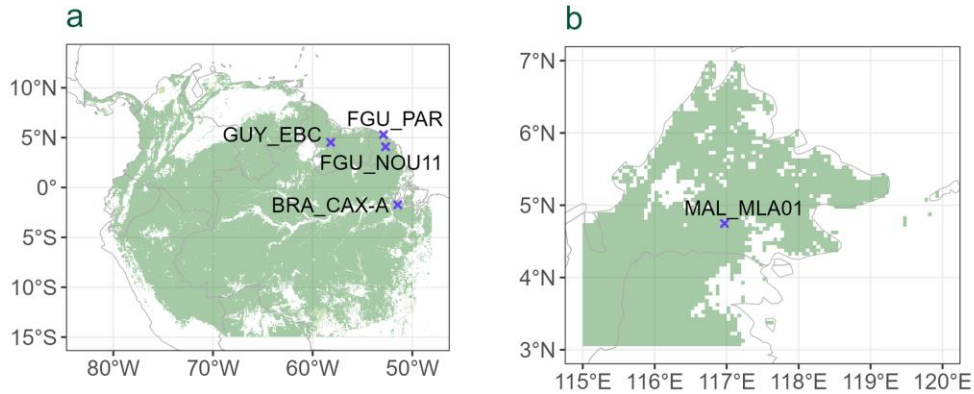


TLS based H:D
model
=
reference

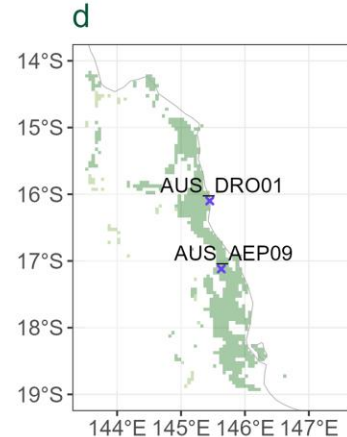
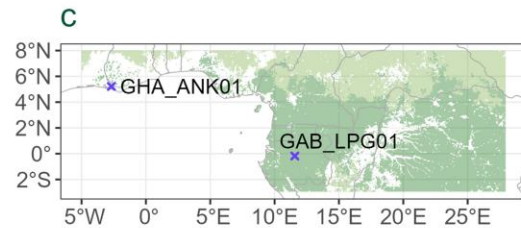
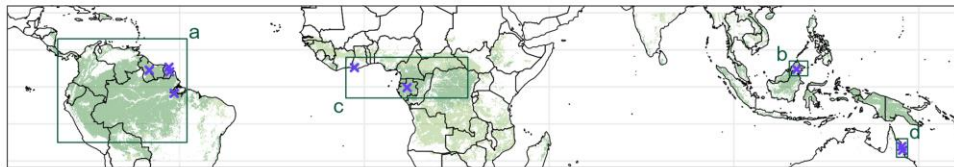


STUDY 2: METHODS

11 tropical rainforest sites



- Stem diameter
- Tree height

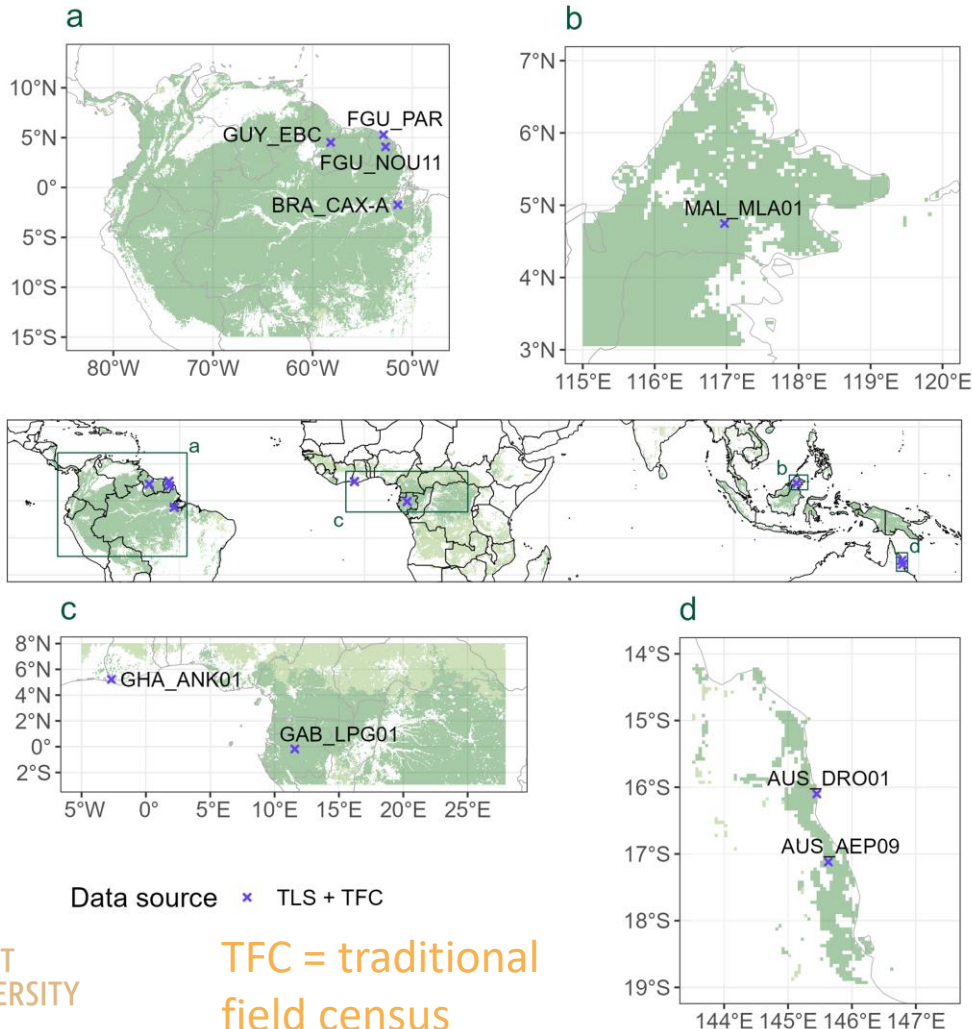


Data source x TLS + TFC

TFC = traditional
field census

STUDY 2: METHODS

11 tropical rainforest sites



- Stem diameter
- Tree height



4 functional forms

$$\ln(H) = a + b \ln(D) + \epsilon$$

$$\ln(H) = a + b \ln(D) + c \ln(D)^2 + \epsilon$$

$$\ln(H) = a + \ln(1 - \exp(-bD^k)) + \epsilon$$

$$\ln(H) = a + b \ln(D) - \ln(k + D^b) + \epsilon$$

Tree height measurement method as a fixed effect on each possible combination of model parameters.



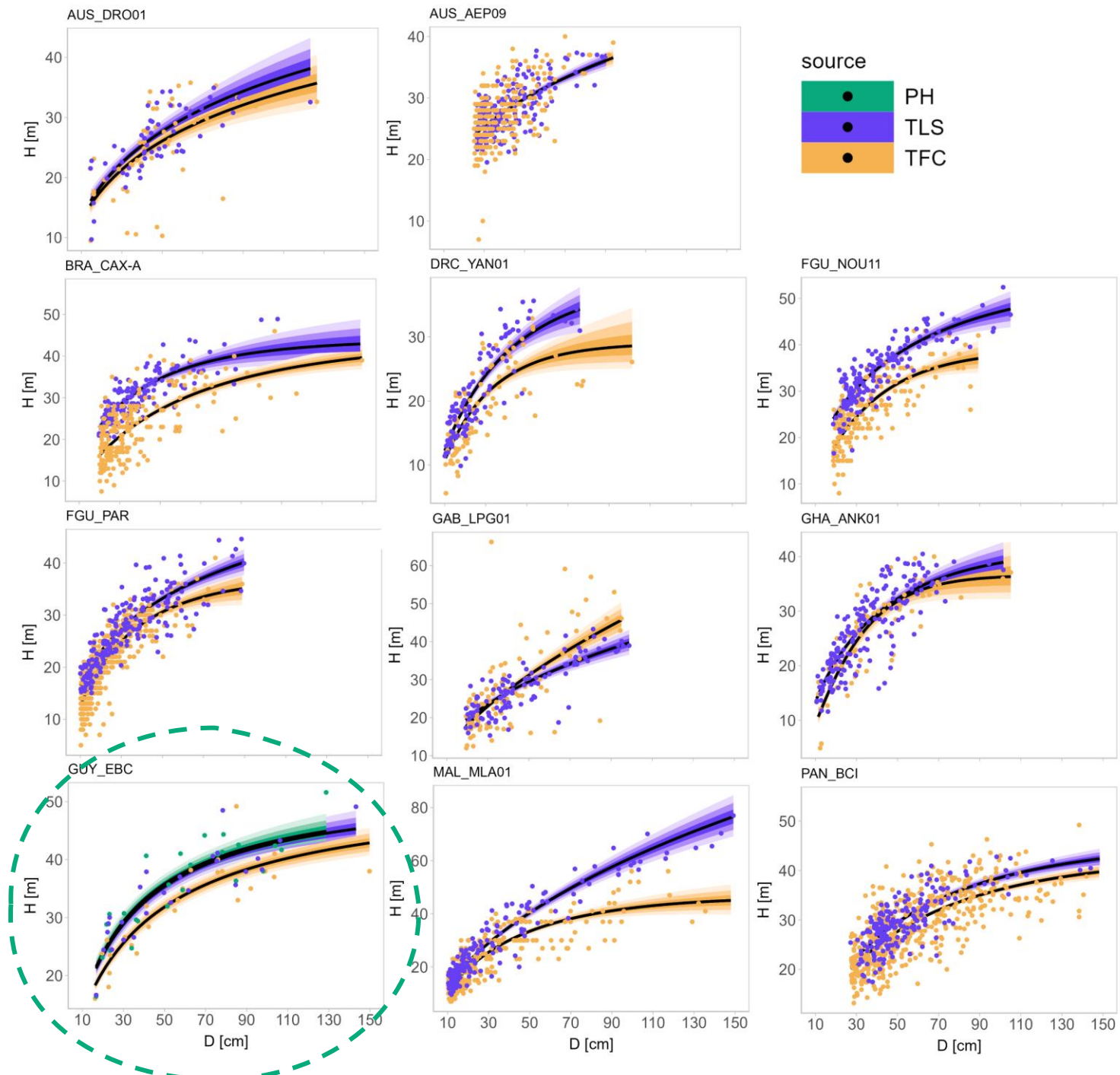
select best model
(Leave-One-Out cross validation)



STUDY 2: RESULTS

H:D model built on stem diameter and tree height data from

- PH = post harvest (destructive)
- TLS = terrestrial laser scanning
- TFC = traditional field census



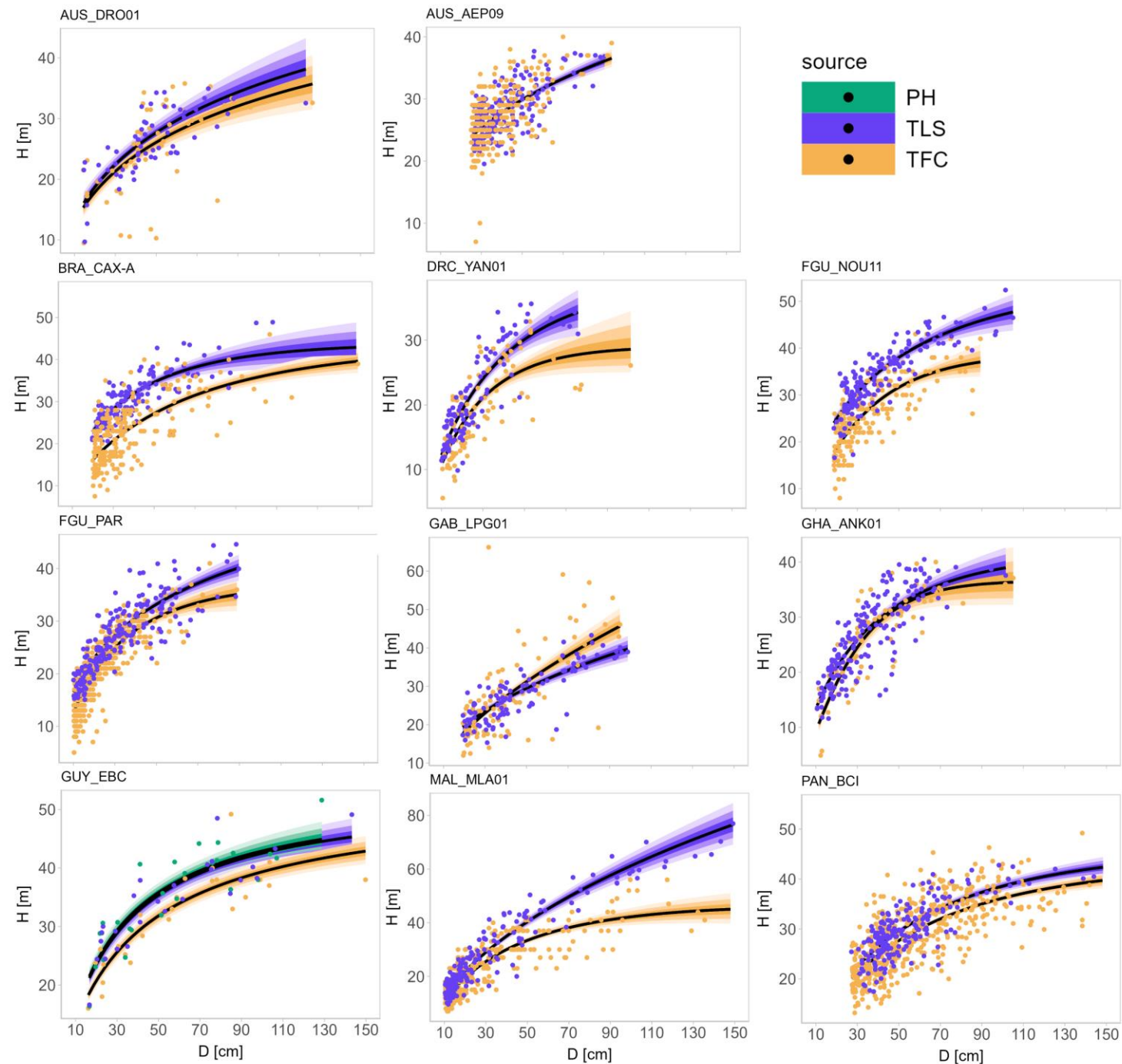
STUDY 2: RESULTS

H:D model built on stem diameter and tree height data from

- PH = post harvest (destructive)
- TLS = terrestrial laser scanning
- TFC = traditional field census



Tree of 30 m
→ TFC based H:D
underestimation of
[-1.9 m, -7.6 m]



STUDY 3: OBJECTIVE

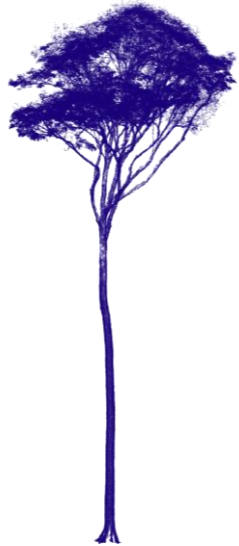
Develop open-access tool to easily calculate structural metrics from 3D tree data



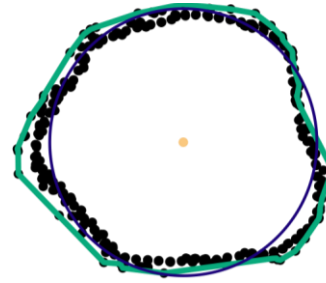
ITSMe = Individual Tree Structural Metrics

STUDY 3: RESULTS

Tree point cloud



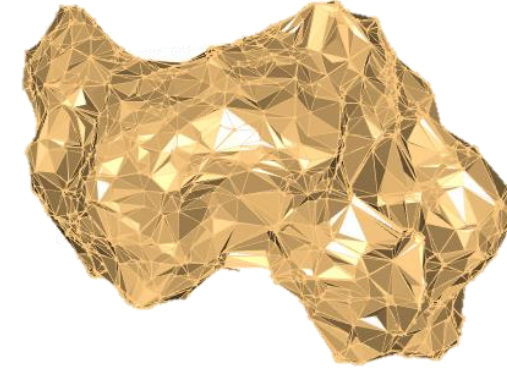
$H = 26.3 \text{ m}$
 $D = 46 \text{ cm}$
 $CPA = 105 \text{ m}^2$
 $CV = 350 \text{ m}^3$



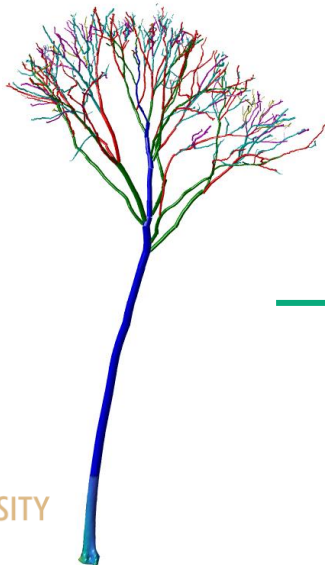
- concave hull
- estimated center
- fitted circle
- points stem slice



- concave hull
- points



Tree QSM



Structural metric	Definition
Stem branch angle	Median of the branching angles of the 1st order branches in degrees. 0 is upwards and 180 downwards (parallel with the trunk). [°]
Stem branch cluster size	Average number of 1st order branches inside a 40cm height interval for 1st order branches. Each branch can only belong to one interval.
Stem branch radius	Mean ratio between the 10 largest 1st order branches measured at the base and the tree height.
Stem branch length	Average length of 1st order branches normalised by the tree height.
...	...



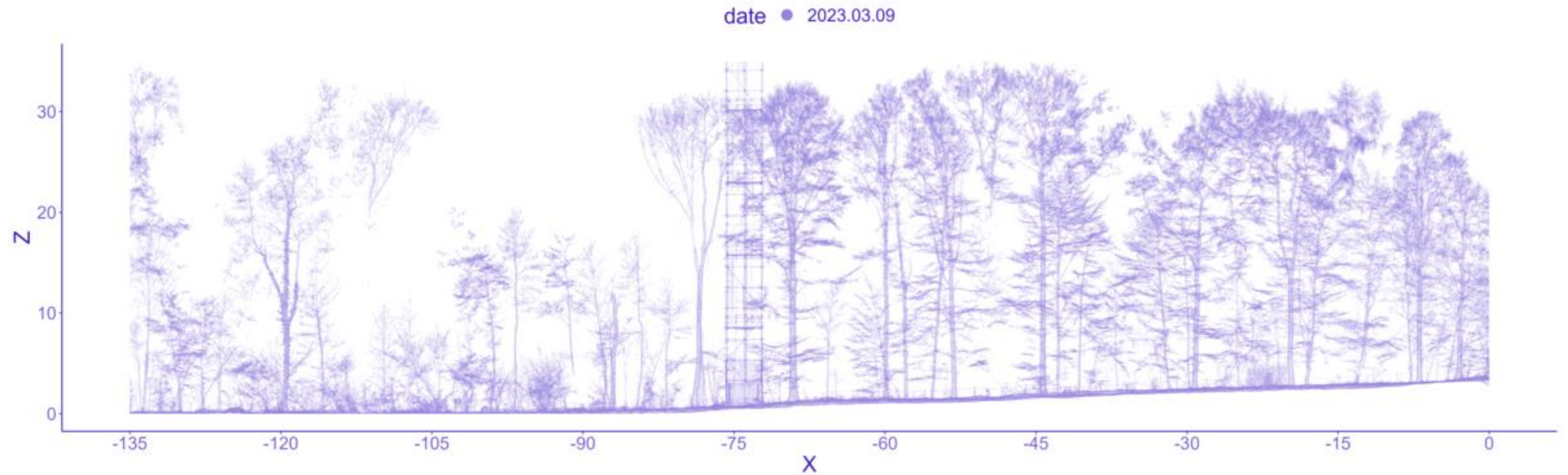
Full paper



ITSMe GitHub

OUTLOOK

- Multi-temporal TLS
 - Forest structural dynamics
 - Tree growth

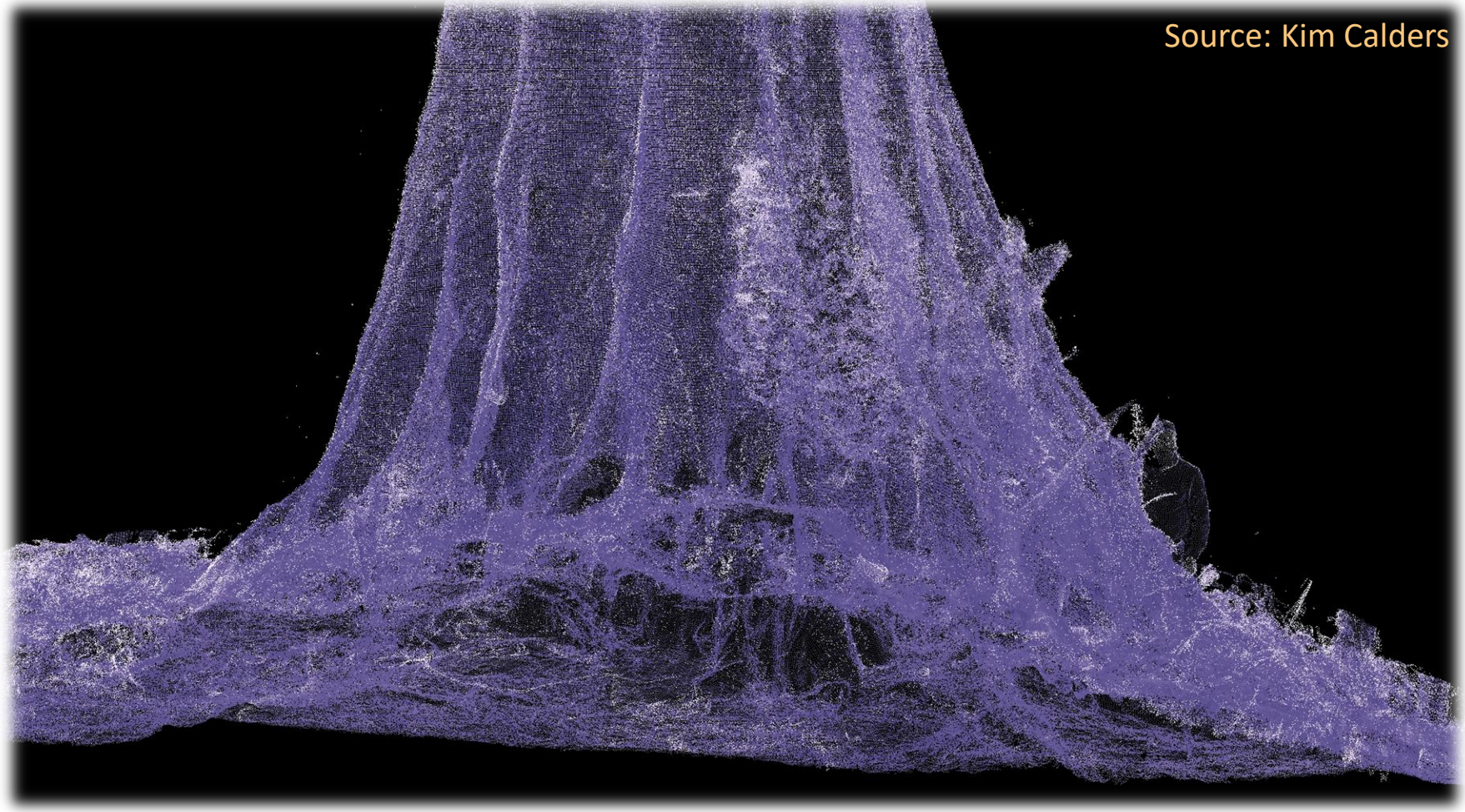


OUTLOOK

- Canopy laser scanning



Source: Kim Calders



Source: Kim Calders

More info?

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https://sketchfab.com/CAVElab_Ugent

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Fusion paper



Full paper

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Full paper

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