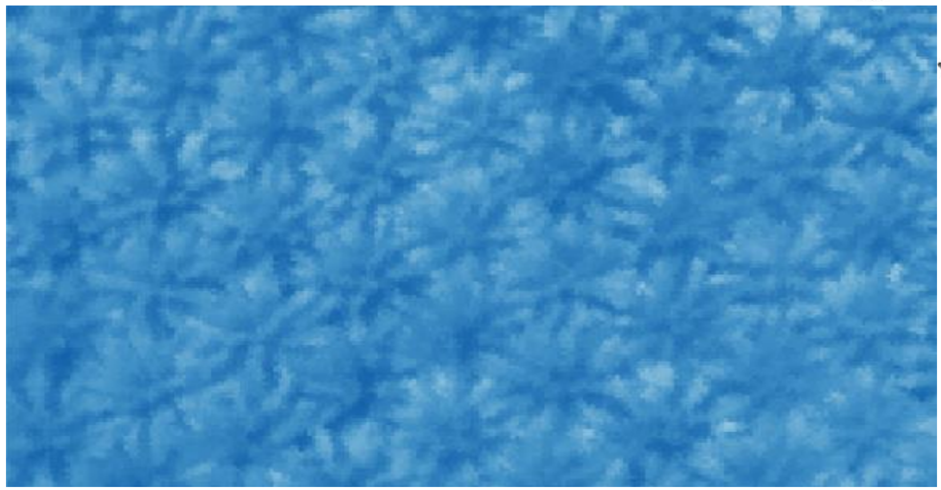
Predicting evapotranspiration from drone-based thermography - a method comparison in an oil palm plantation



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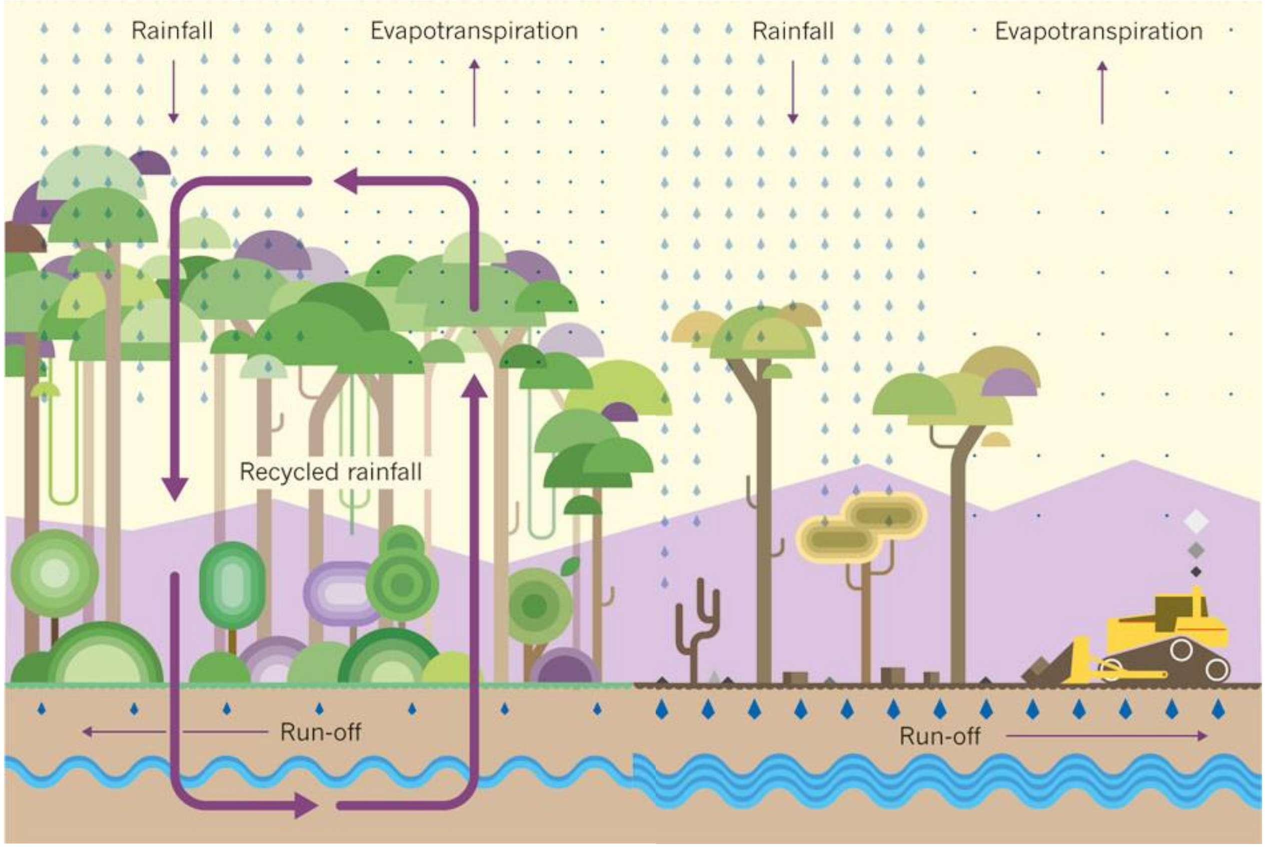
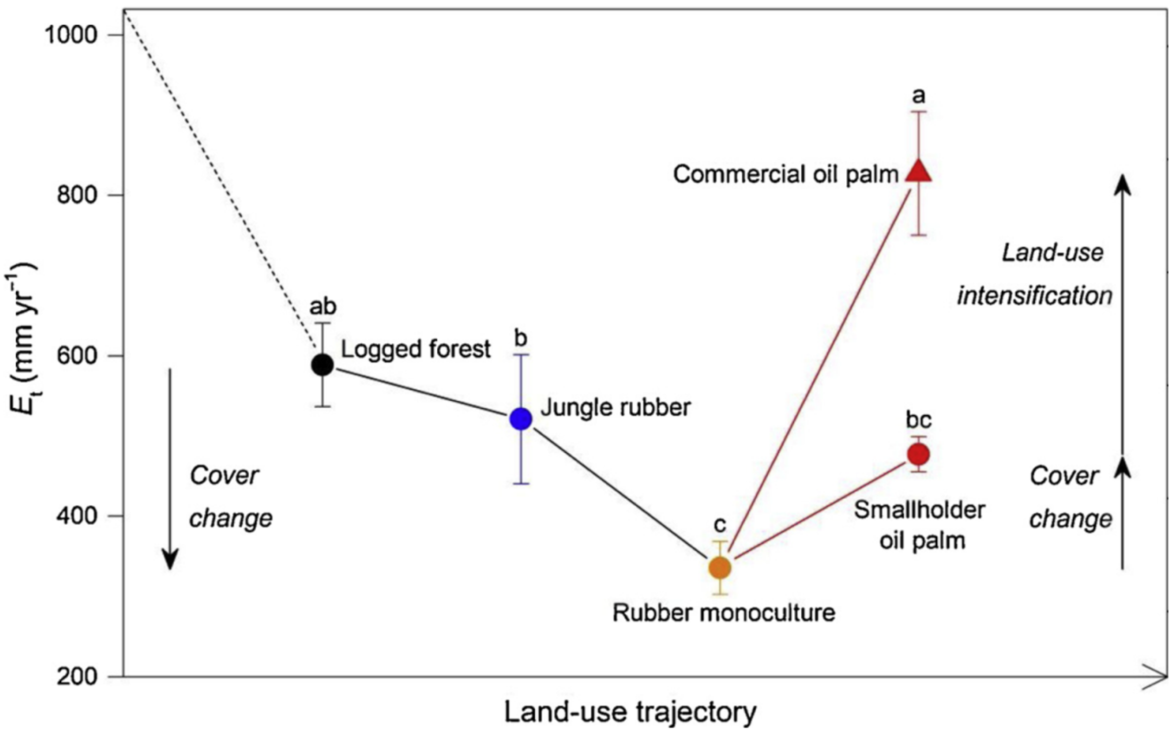
Evapotranspiration is a key flux in the hydrological cycle

Globally, ~60% of terrestrial precipitation are recycled as evapotranspiration (ET)
Land-use and climate changes potentially alter ET



Aragao, 2012

Example land-use change: transpiration (E_t) was substantially altered along a common land-use trajectory in lowland Sumatra



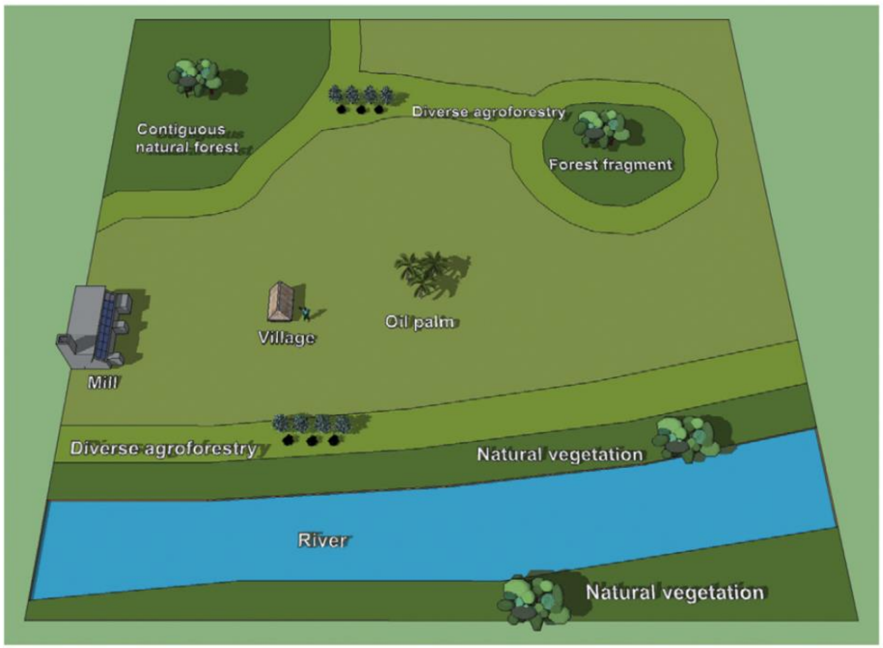
42 study sites across 5 land-use types

E_t was estimated with a sap flux approach

Röll et al., 2019

Complex, dynamic landscapes require flexible ET estimation methods that can cover large areas with high spatial and temporal resolution

Example of an oil palm transformation frontier



Koh et al., 2009

Problem for landscape-scale ET assessments: various land-use types in a single landscape

Potential methods for landscape ET assessments

- Eddy covariance (EC) method
  Problem: commonly too few towers per landscape
- Satellite thermography (and subsequent energy balance modeling)
  Problem: spatial and temporal resolution of satellite images often insufficient; cloud cover
- **Drone-based thermography and subsequent energy balance modeling**
  A recent, complementary approach that can potentially overcome the mentioned problems

Objectives of the presented study

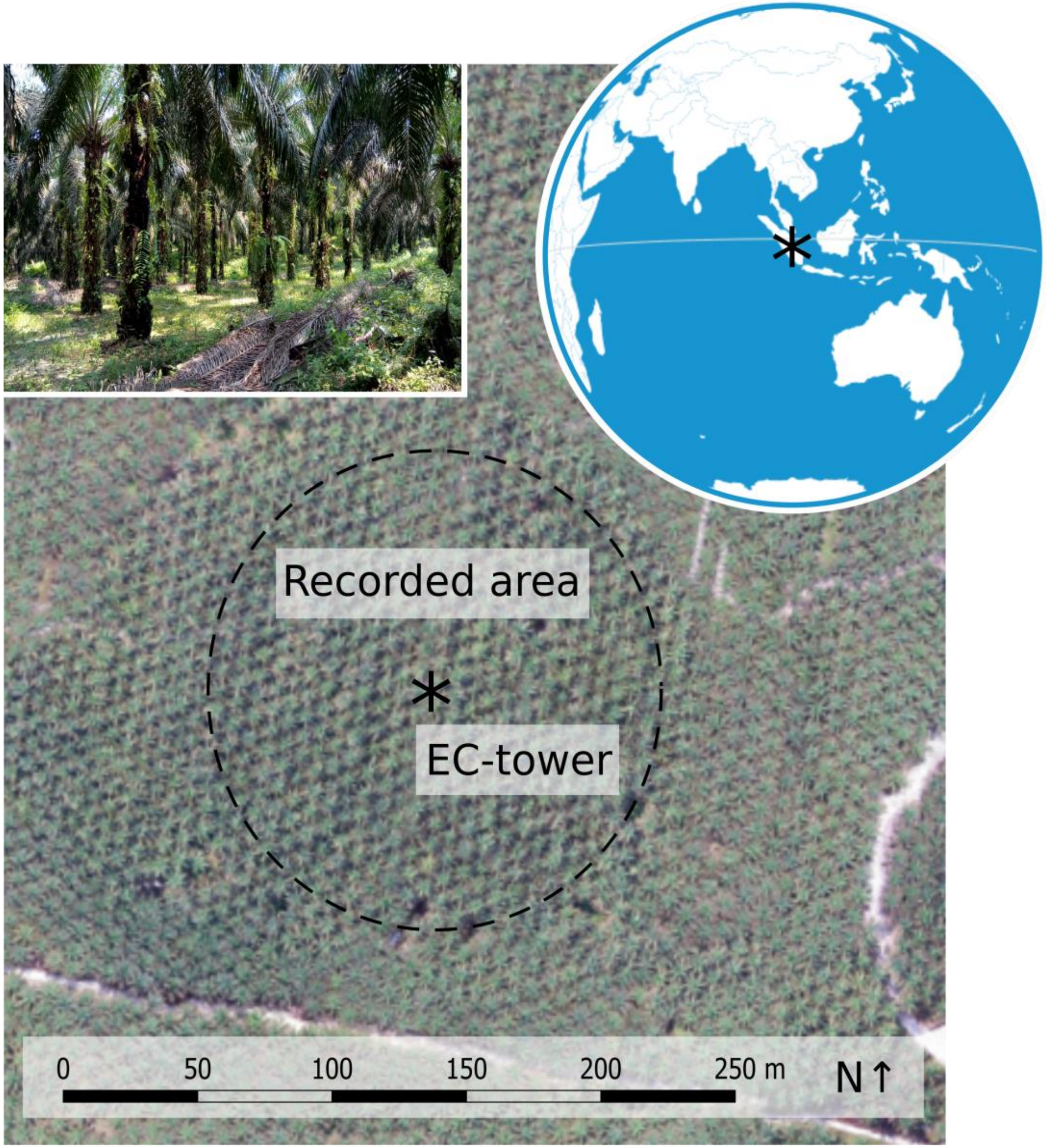
Drone-based thermography for estimating ET has successfully been applied in some European agricultural systems in previous studies (e.g. Hoffmann et al., 2016; Brenner et al., 2018).

However, the method has not yet been tested in the tropics and for higher vegetation such as oil palms.

The specific objectives of our study were:

1. To compare ET estimates from the drone-based methods to the reference EC technique and identify the best-performing model

2. To provide a first example of spatially explicit, high resolution ET maps in an oil palm plantation



Methods

<u>Study site</u>
Mature oil palm monoculture plantation in the lowlands of Jambi, Sumatra, Indonesia

Covers most of the potential footprint of an eddy covariance (EC) tower at its center

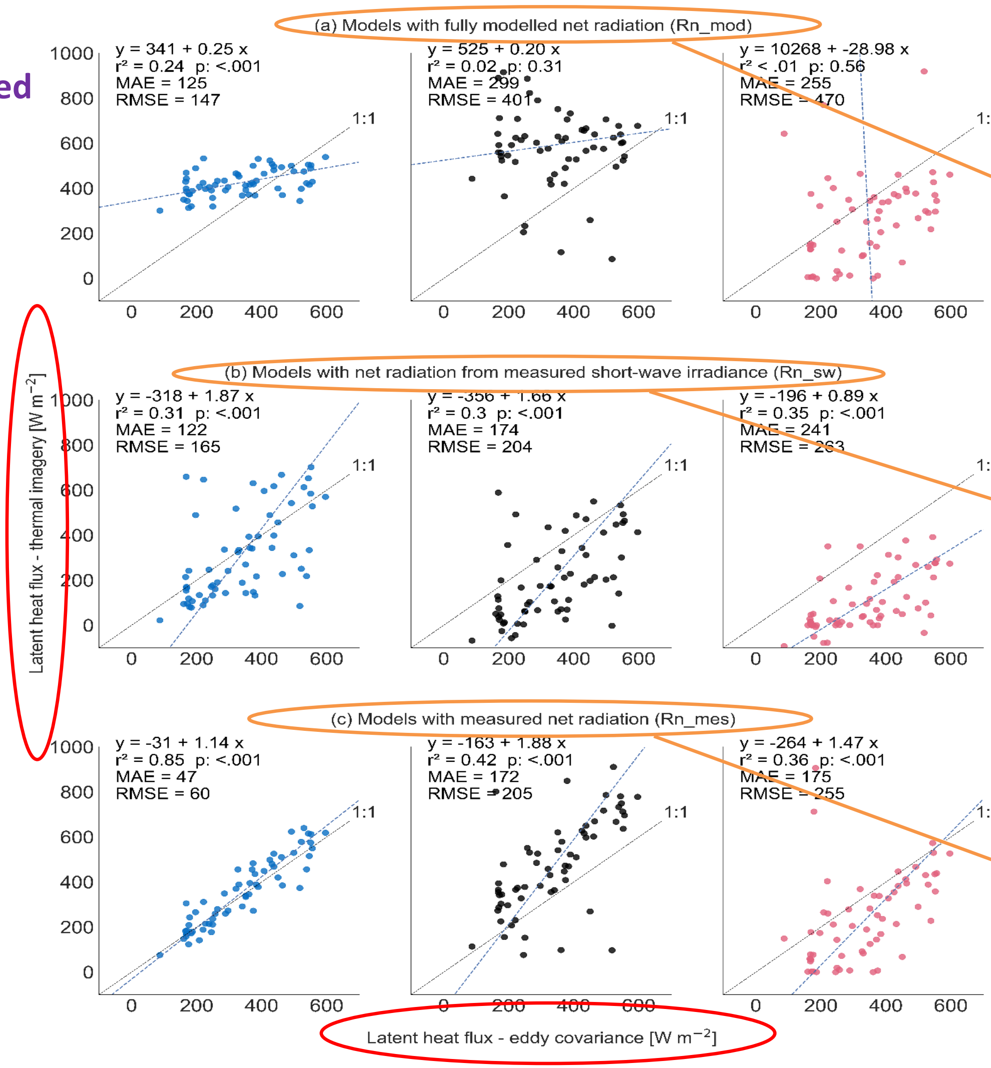
<u>Method test approach</u>
ET from drone-based thermography vs. simultaneous EC measurements

Ellsäßer et al., in prep.

Overview of the structure of the subsequently presented results

3 different energy balance models for modeling ET from drone-based thermography

DATTUTDUT **TSEB-PT** **DTD**



3 different configurations to include net radiation (Rn) into each model

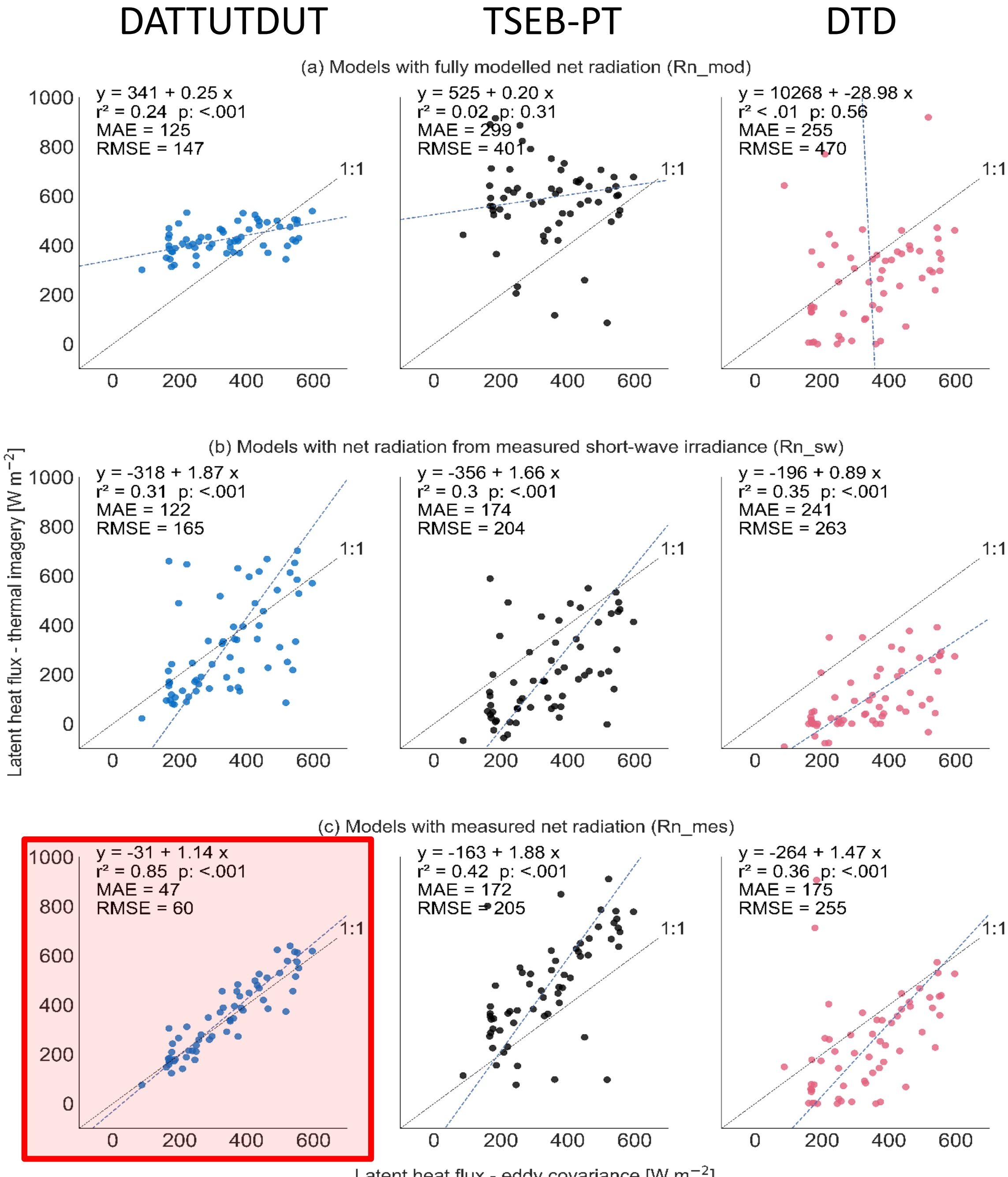
(a) Fully modeling Rn from location and time data

(b) Modeling Rn from short-wave irradiance measurements

(c) Using directly measured Rn

<u>y-axes:</u> Latent heat flux derived from the drone-based methods; here, latent heat flux is displayed in W m^{-2}; it could also be presented as ET in mm h^{-1}.

<u>x-axes:</u> Latent heat flux (W m^{-2}) derived from simultaneous EC reference measurements



Ellsäßer et al., in prep.

Key results

Fully modeled Rn as input

Somewhat acceptable results only with DATTUTDUT
(this is the original Rn-input configuration of DATTUTDUT)

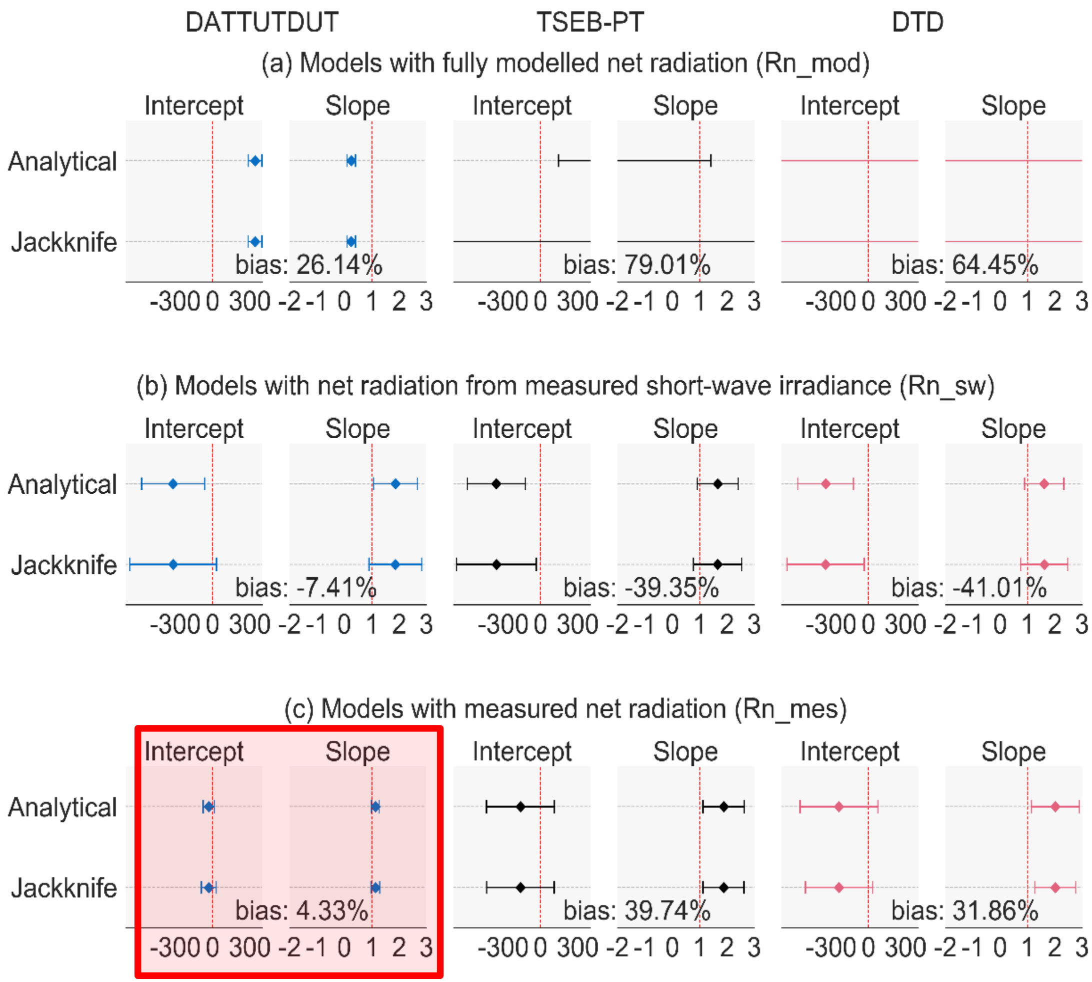
Rn from short-wave irradiance

Substantial improvements for TSEB-PT and DTD
(adapted configuration of TSEB-PT and DTD, Guzinski et al., 2013)

Directly measured Rn

Further improvements, particularly for DATTUTDUT (R^2=0.85, P<0.001)
(this is the original Rn input configuration of the EC method, the TSEB-PT and the DTD)

A deming regression even indicates interchangability between DATTUTDUT with measured Rn and the eddy covariance method



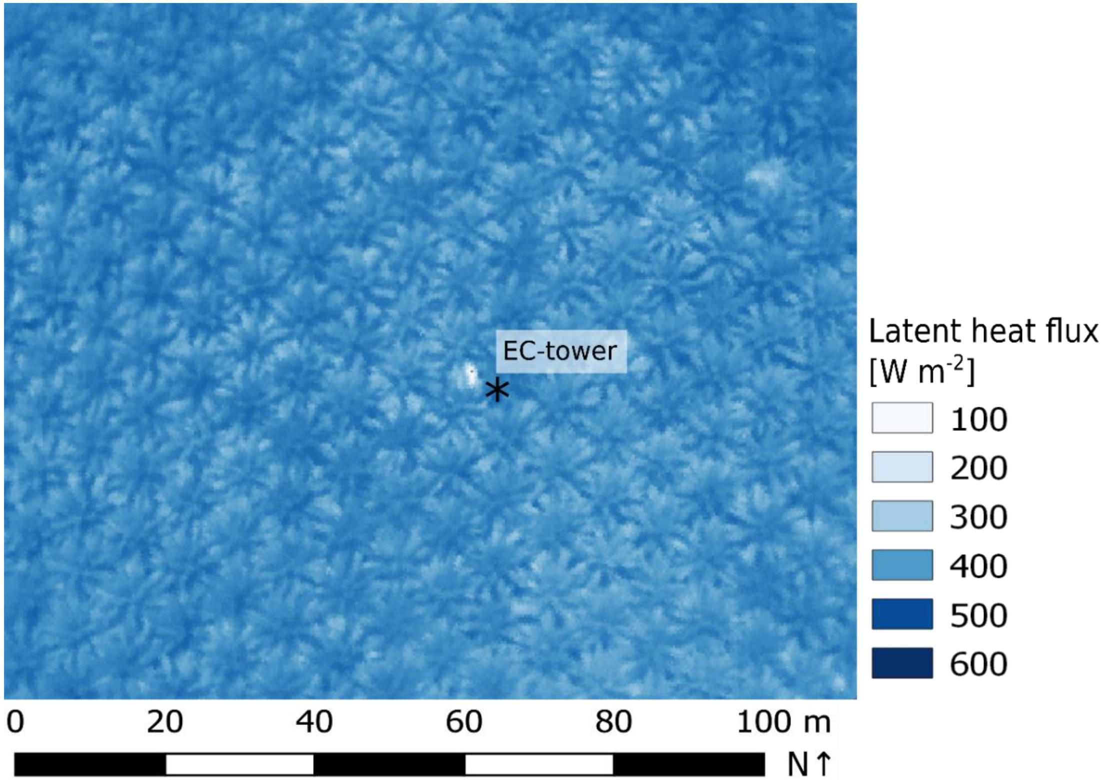
Intercept and slope of the regressions between drone-derived ET and EC-derived ET were compared analytically and with a jackknife approach

<u>DATTUTDUT with measured Rn</u>

The means (dots) and confidence intervals (error bars) of intercept and slope suggest interchangability with the reference EC method

Ellsäßer et al., in prep.

Large potential of the drone-based method for spatially explicit, fine-grain analysis of ET



The best-performing model was applied (DATTUDDUT with measured Rn)
Depicted here: ET in the vicinity of the EC tower on 9 August 2017 at 12.30 pm.

Ellsäßer et al., in prep.

Conclusions and outlook

Drone-based thermography and subsequent energy balance modeling under certain configurations (here: DATTUTDUT with measured Rn) can be considered a highly reliable method for estimating latent heat flux and evapotranspiration.

They complement the asset of available methods for evapotranspiration studies by fine grain and spatially explicit assessments.

For further validation and enhancement of the method, we envision in the near future:

- Testing the different models and configurations against EC reference measurements across different land-use types and along a large gradient of drought stress (temperate > Mediterranean > semi-arid)

- Testing Rn measurements directly on-board the drone vs. Rn measurements on EC towers as the basis for establishing the method as an accurate, stand-alone ET estimation approach beyond EC sites

Thanks a lot for your interest!

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