GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

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Effects of land-use change on land-atmosphere exchange processes in Indonesia

SFB 990

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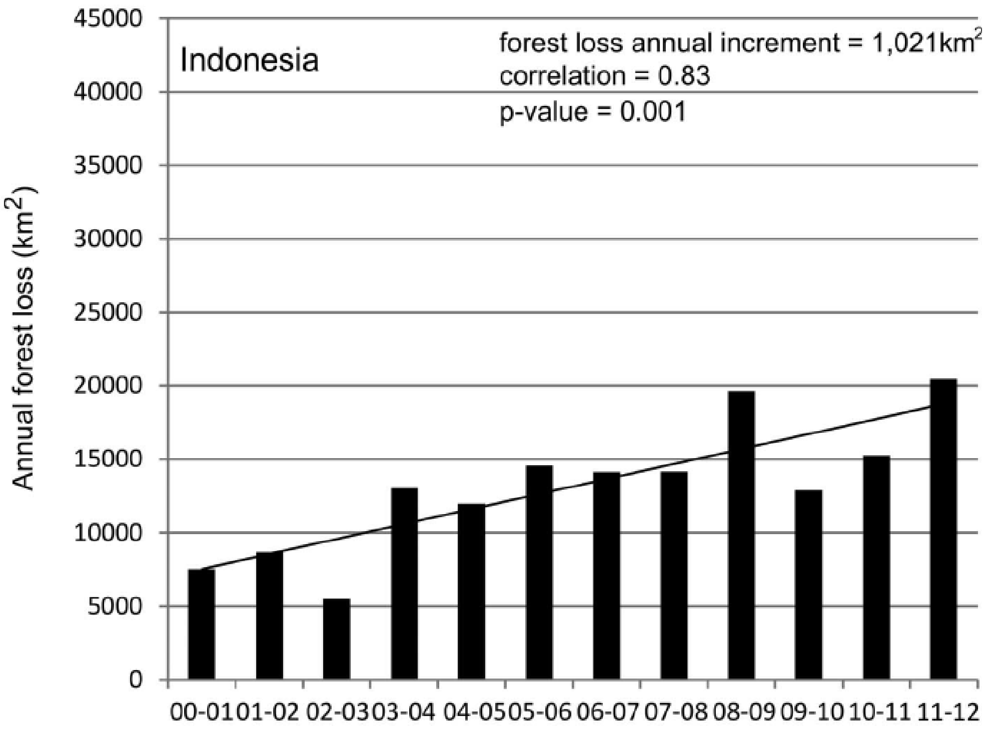
Indonesia = hotspot for biodiversity

More than 15 000 endemic plant species
More than 1000 endemic vertebrate species
(Myers et al. 2000)

… and for forest loss



Hansen et al. 2013

Forest loss

- 2012 → highest total primary forest loss in Indonesia (0.84Mha), surpassing Brazil (Margono et al. 2014)

- Main drivers of land-use change in Sumatra (Laumonier et al. 2010)
    - Transmigration programs, oil palm and rubber plantations, and timber industry

- Land-use change makes Indonesia 3rd largest CO_2 emitter globally (PEACE report, 2007)

Palm oil and palm kernel oil based ingredients are found in approximately 50% of products on supermarket shelves, including food and non food items.

Oil palm expansion

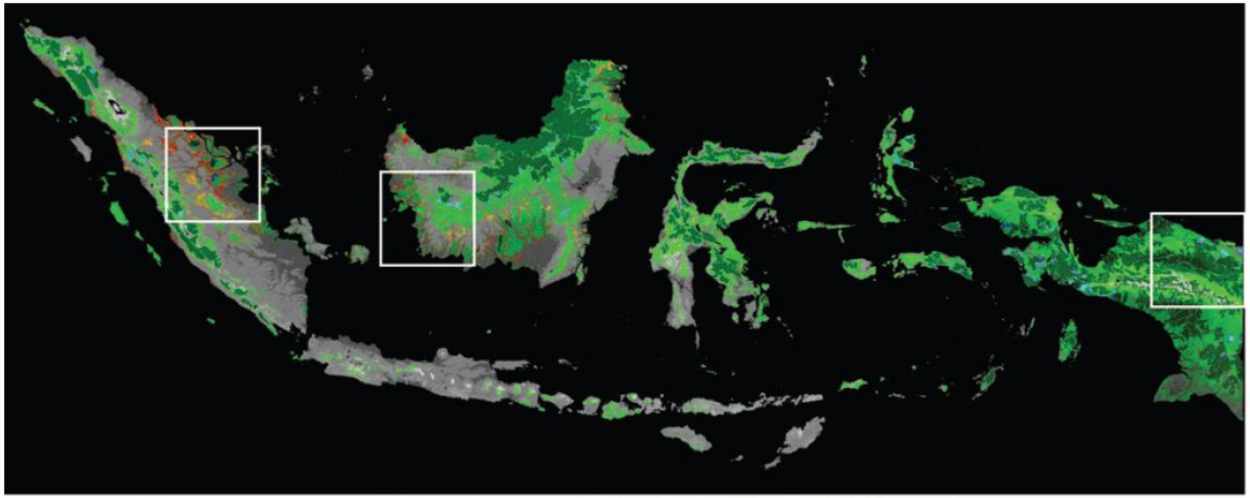
- Oil palm (*elaeis guineensis*) plantations in Sumatra and Kalimantan are responsible of nearly half of the world’s oil palm production (Carlson et al., 2012)

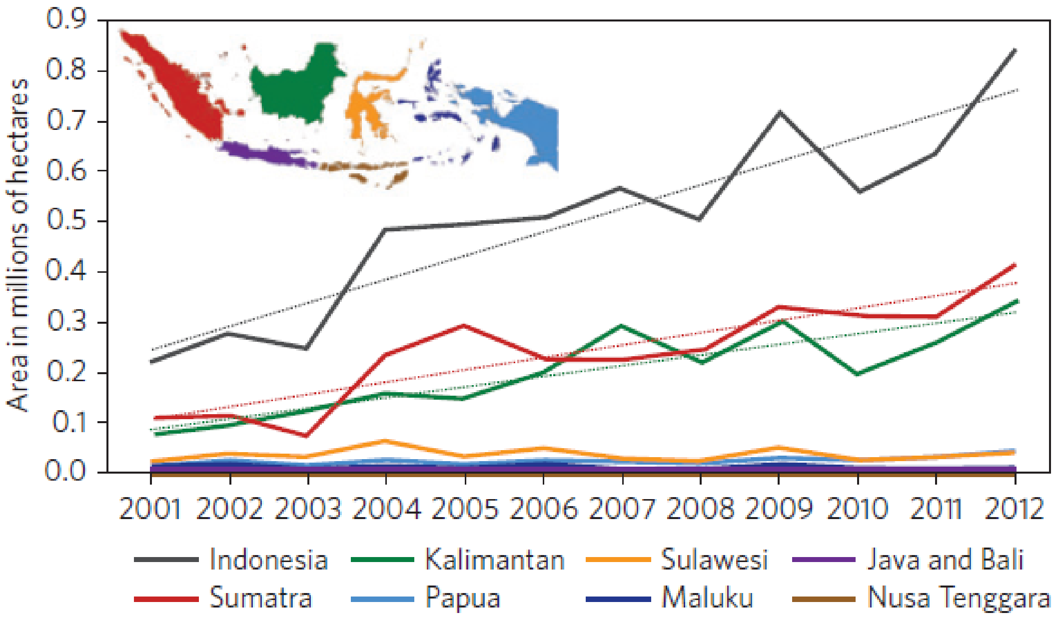
- Indonesia plans to duplicate the surface dedicated to oil palm cultivation in the next years

Palm oil used for biodiesel

- 15% percent of the produced palm oil is used for biofuel
- Renewable Energy Directive of the EU (2018): biofuels must reach
  - ≥ 60% GHG savings in comparison to fossil fuels for production starting before 2020
  - ≥ 65% GHG savings for production starting 2021-2026
  - ≥ 80% GHG saving for production starting after 2026
- Studies assessing the impact of palm-oil biodiesel very limited (Archer et al. 2018)
  - life cycle analysis (LCA) considers cultivation phase as CO_2 neutral: CO_2 absorbed = CO_2 released when burning biodiesel
  - LCA analysis based on field measured data not available

Sumatra = past, Kalimantan = present , Papua = future

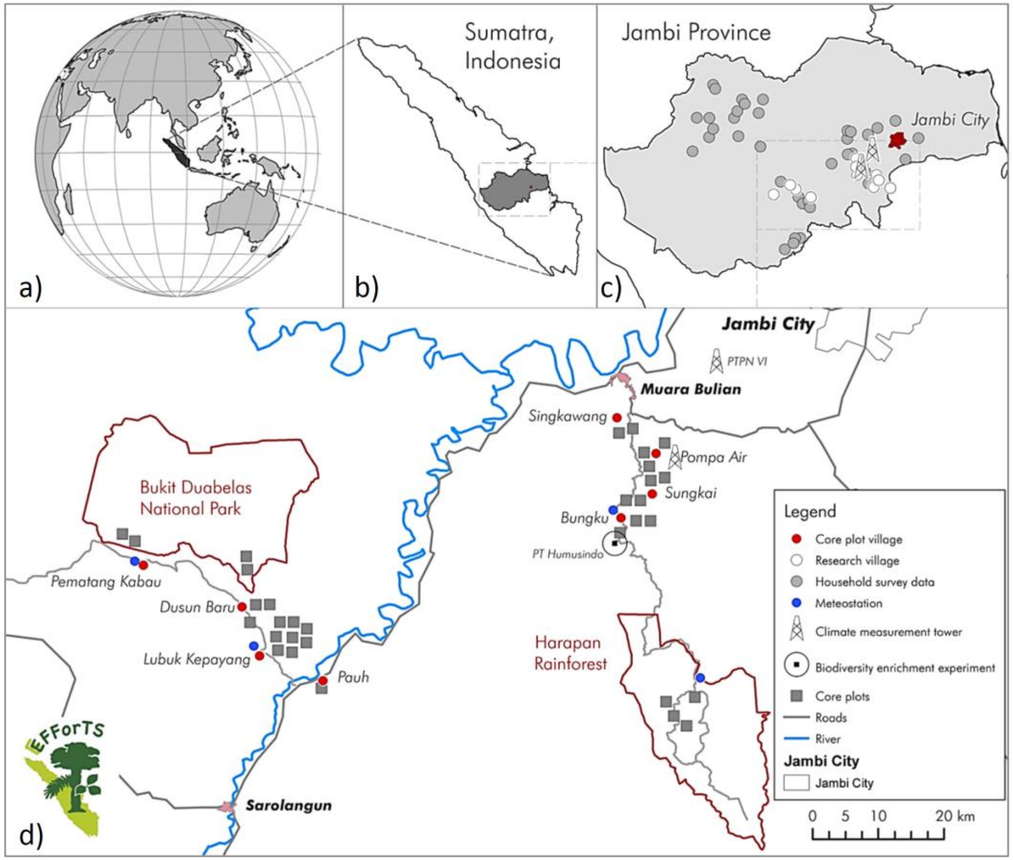




Margono et al. 2014

EFForTS - Ecological and Socioeconomic Functions of Tropical Lowland Rainforest Transformation Systems

- Coordinated Research Center 990 (funded by DFG)
- Research area: Lowland rainforest on mineral soil
- Integration of ecological and socioeconomic studies (25 projects)
- Core plot design: Two regions with remaining lowland rainforests with oil palm, rubber, jungle rubber (n = 8)



Drescher et al. 2016

Objectives of EFForTS

1) **to identify ecological and socio-economic functions** of lowland tropical land-use systems and understand their trade-offs:

- Lowland rainforest (F)
- Jungle rubber (J)
- Rubber plantations (R)
- Oil palm plantations (O)

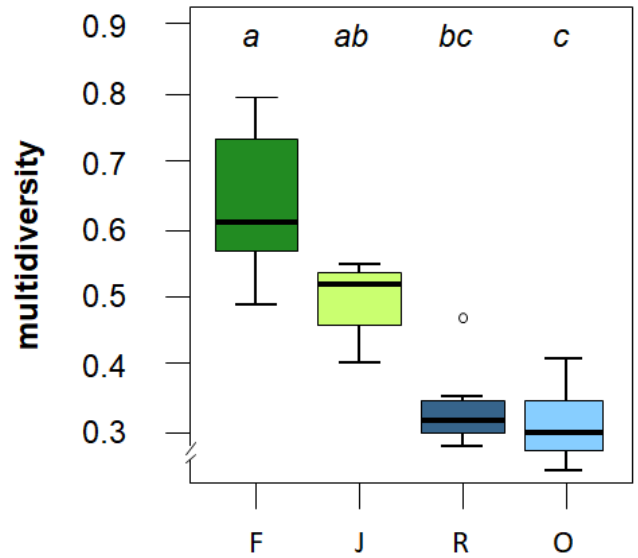
2) **to quantify the effect of land transformation on the carbon, water and energy exchange with the atmosphere**

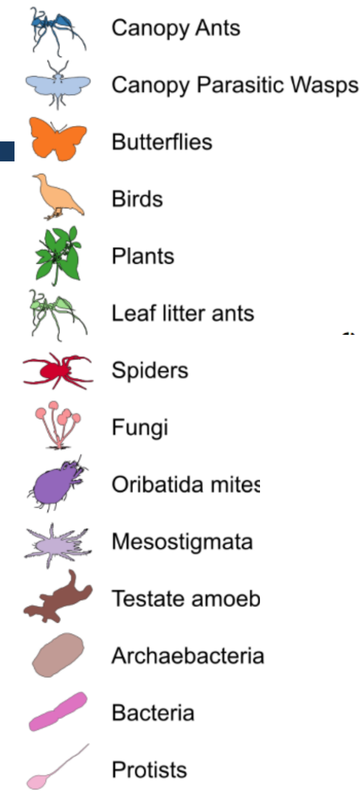






Strong losses in biodiversity





Old-growth forest (F)

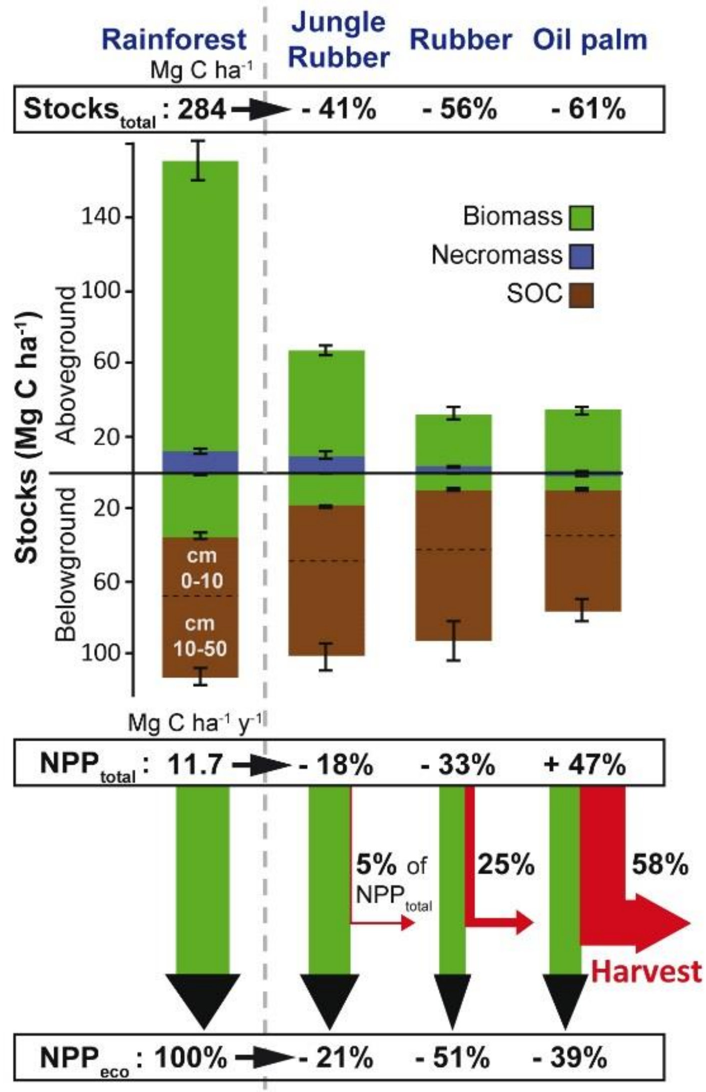
Jungle rubber (J)

Rubber plantation (R)

Oil palm plantation (O)

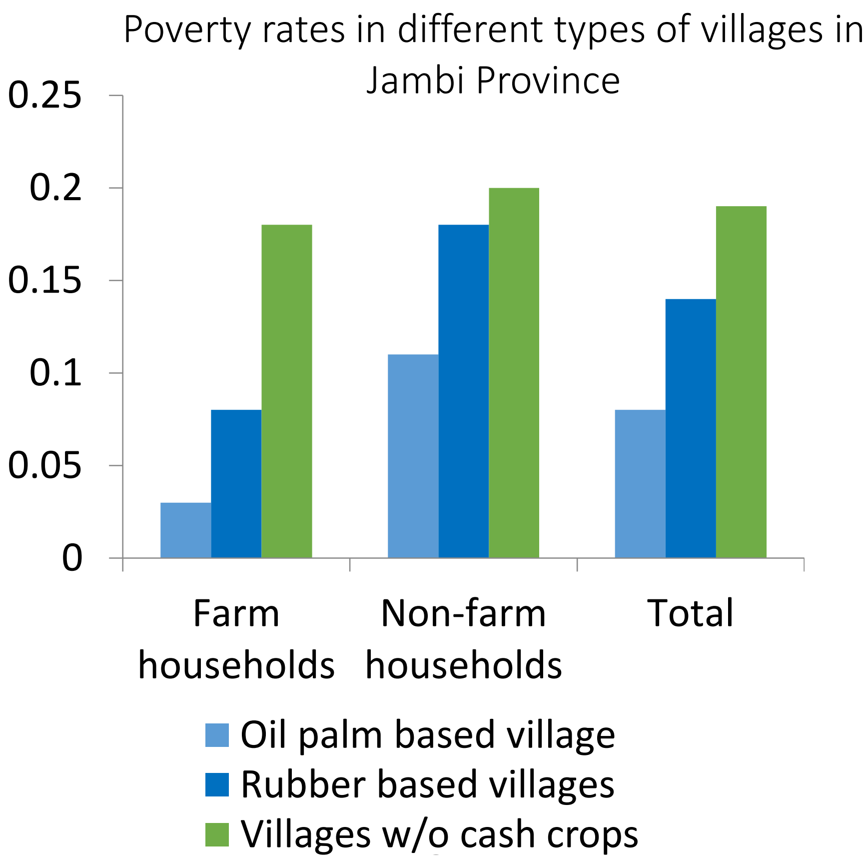
Large loss of stored carbon

- Massive decrease in carbon stocks, mainly in plant biomass with conversion of rainforest
- Increase in NPP in oil palm plantations, but mostly harvested
- Uniform decrease in ecosystem NPP



Guillaume et al. (2018)

Improved household livelihoods



(Bou Dib et al. 2018)

- Positive broader economic and social effects, e.g. reduction of poverty rate
- Oil palm cultivation benefits farm and non-farm households in rural Jambi
- Oil palm is inequality-increasing for farmers but inequality-decreasing for non-farm households
- It also causes some social problems related to land property rights (Beckert et al. 2014, Krishna et al. 2014, Grimm & Klasen 2015)

Effects on greenhouse gas exchange

Study sites

Mean annual temperature: 26.7 ± 0.2°C

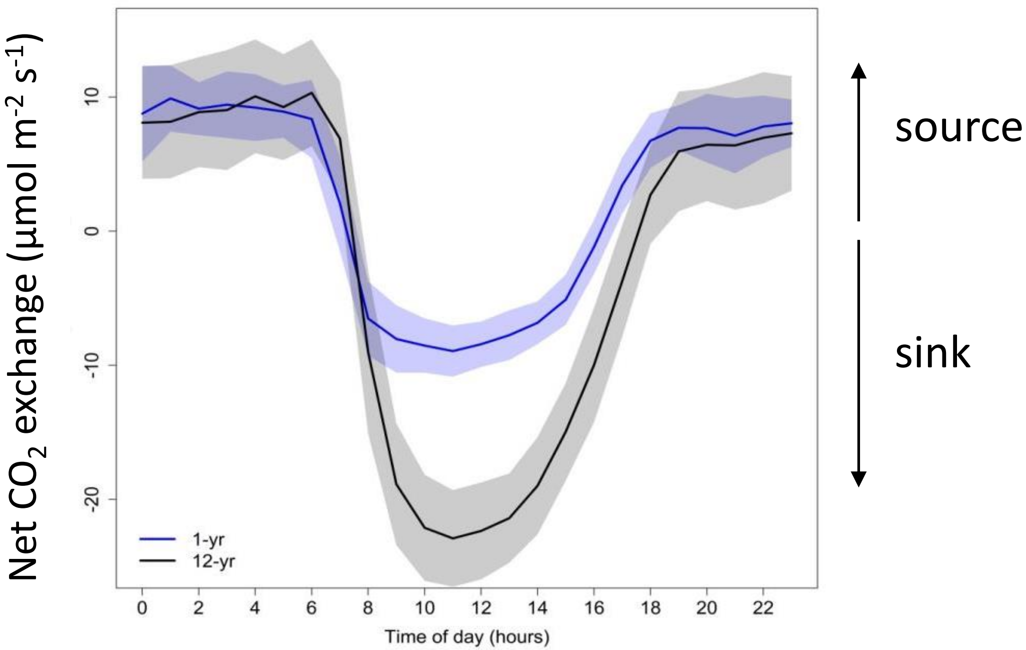
Mean annual rainfall: 2235 ± 385 mm

Measurements taken in two oil palm plantations in the Jambi province, Sumatra

Young – non productive plantation (1-year old)

Mature – productive plantation (12-year old)

Trace gas fluxes: CO_2



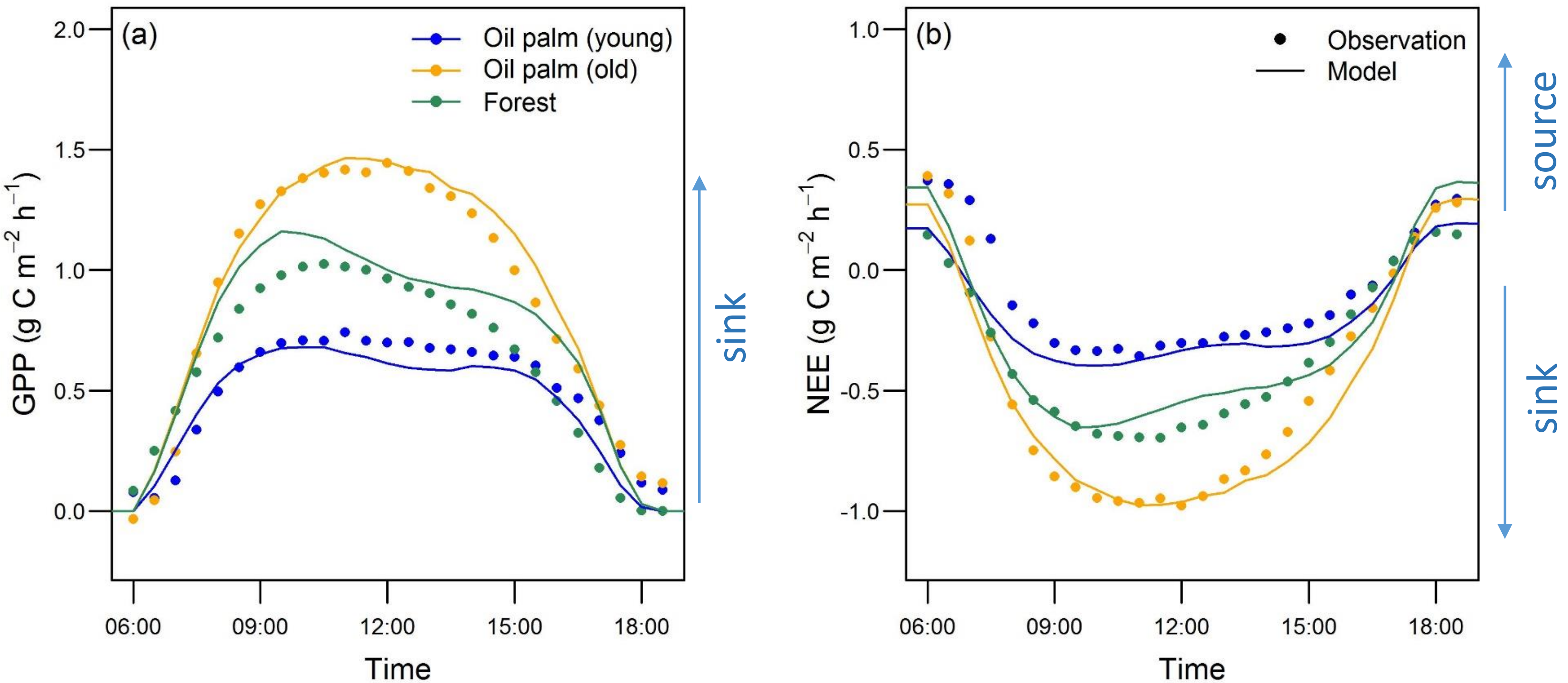
- 1-year old = source (10.0 Mg C ha^{-1} yr^{-1})
- 12-year old = sink (-7.5 Mg C ha^{-1} yr^{-1}) but 9.0 Mg C ha^{-1} yr^{-1} exported via harvest resulting in 1.5 Mg C ha^{-1} yr^{-1} C loss on site

Meijide et al., 2017
Meijide et al., unpubl.

Comparison to Community Land Model

Gross primary productivity

Net ecosystem exchange

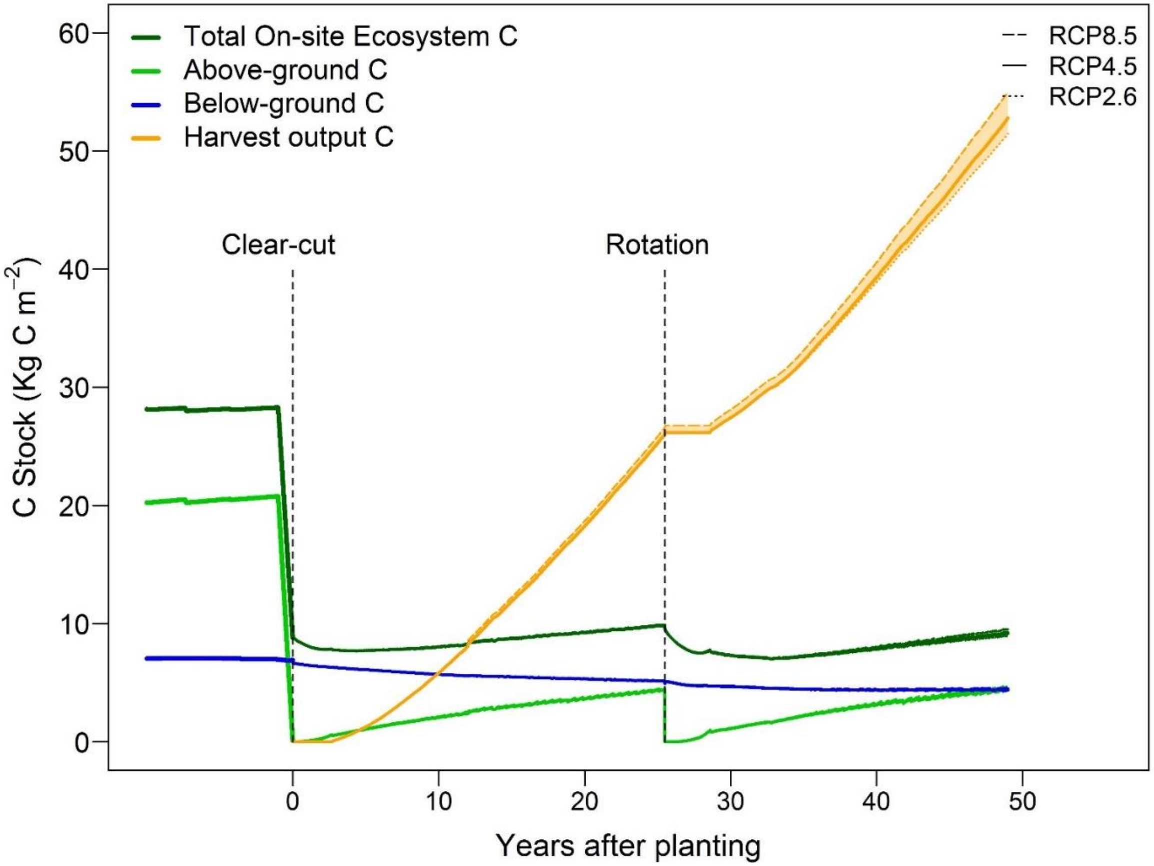


- Forest have net CO_2 uptake between young and old oil palm plantation

Fan et al. 2015
Fan, unpublished

Forest to oil palm transition

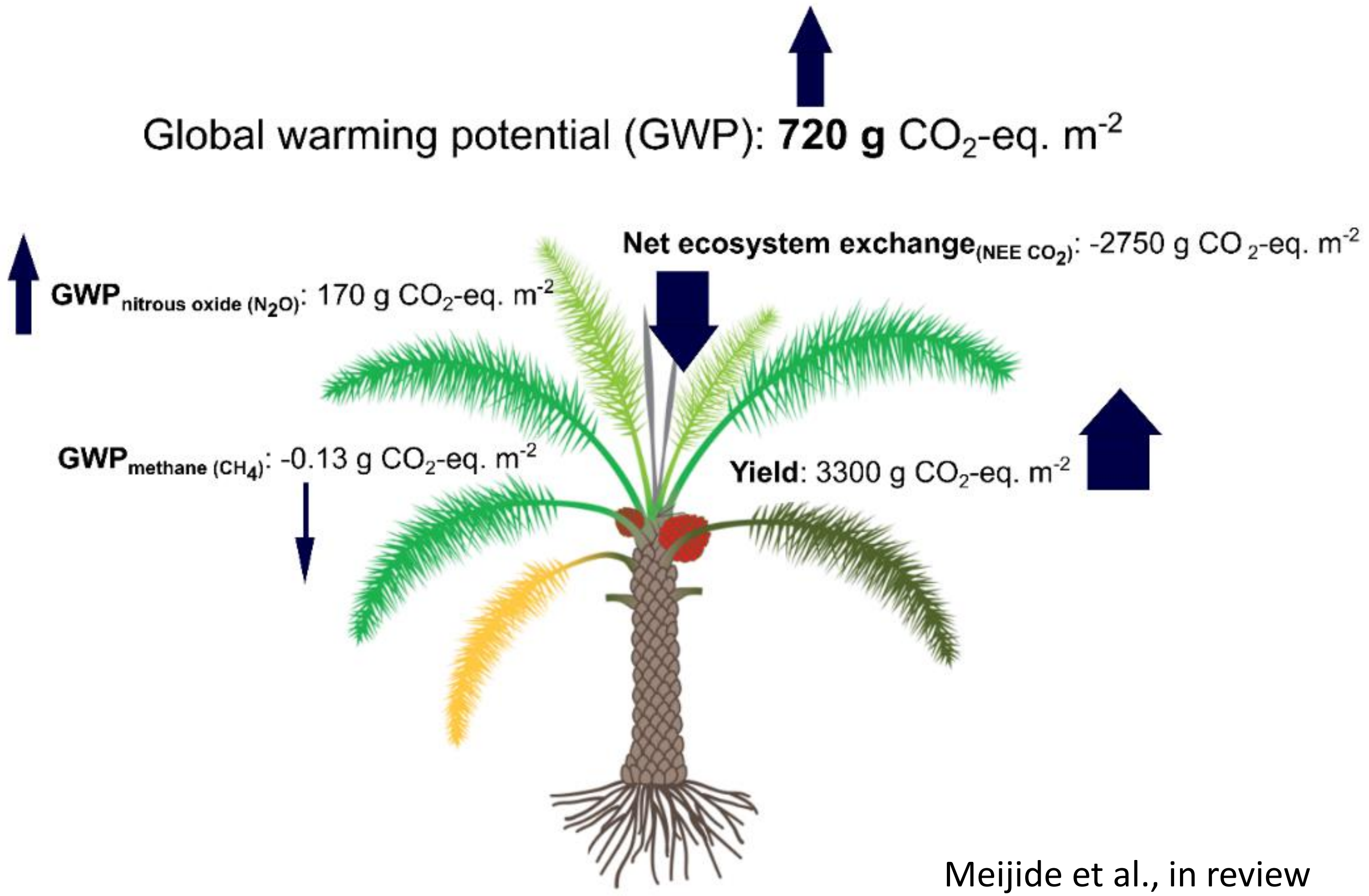
Simulations with Community Land Model 4.5 - Palm



Fan et al. unpublished

- Long-term onsite carbon losses as most carbon is exported
- In line with field observations (Guillaume et al. 2018)

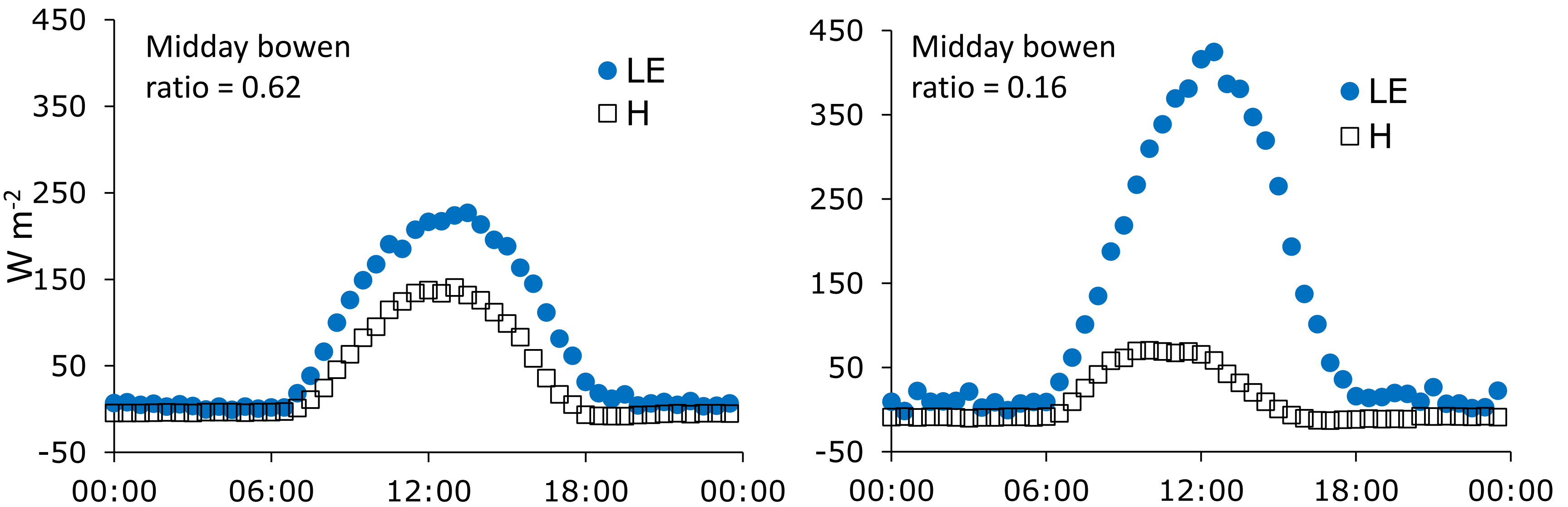
Oil palm plantation served as a net GHG source



Meijide et al., in review
Stiegler et al. 2019

Effects on water and energy exchange

Sensible (H) and latent heat (LE) fluxes



1-year old
(data from Jul 2013 to Feb 2014)

12-year old
(data from May 2014 to Feb 2015)

Meijide et al., 2017

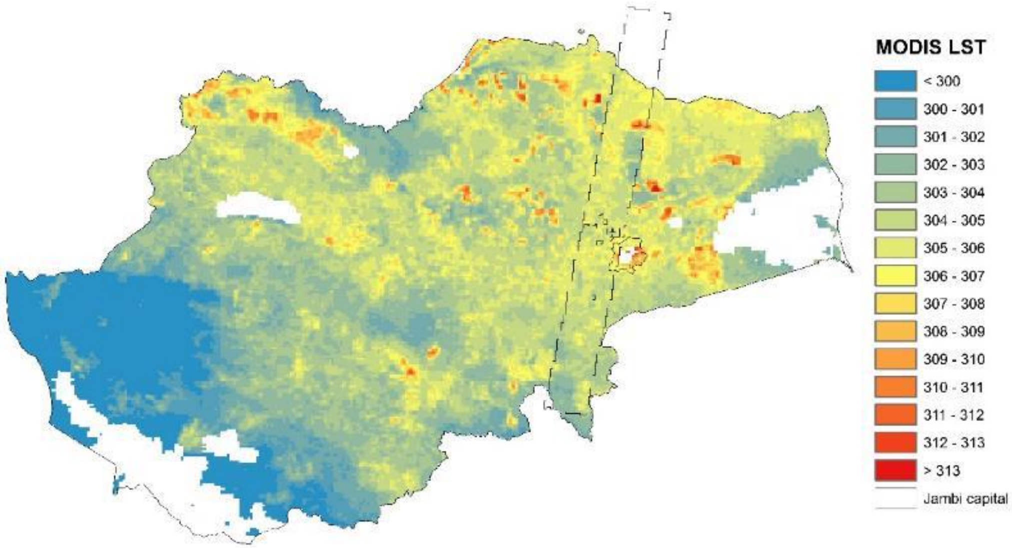
- Greater amount of energy used for latent heat fluxes in 12-yr old plantation
  ➔ 1-yr old plantation should have higher surface temperature

Estimating surface temperature

Satellite data from

- MODIS
- Landsat

- Surface temperature
- Albedo
- NDVI (Vegetation index)



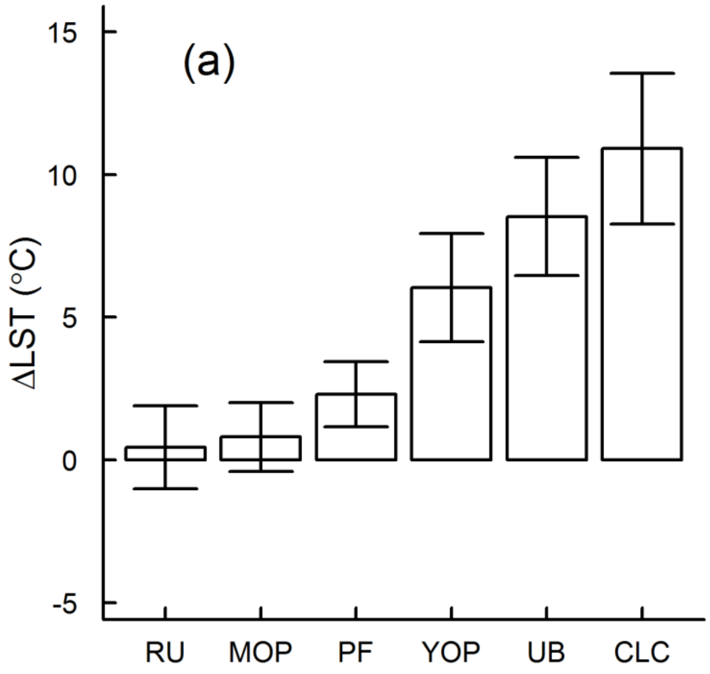
Field data:

36 oil palm plots: 1 – 25 years

5 forest plots: > 25 years

Sabajo et al., 2017

Surface temperature change (ΔTs) compared to forest



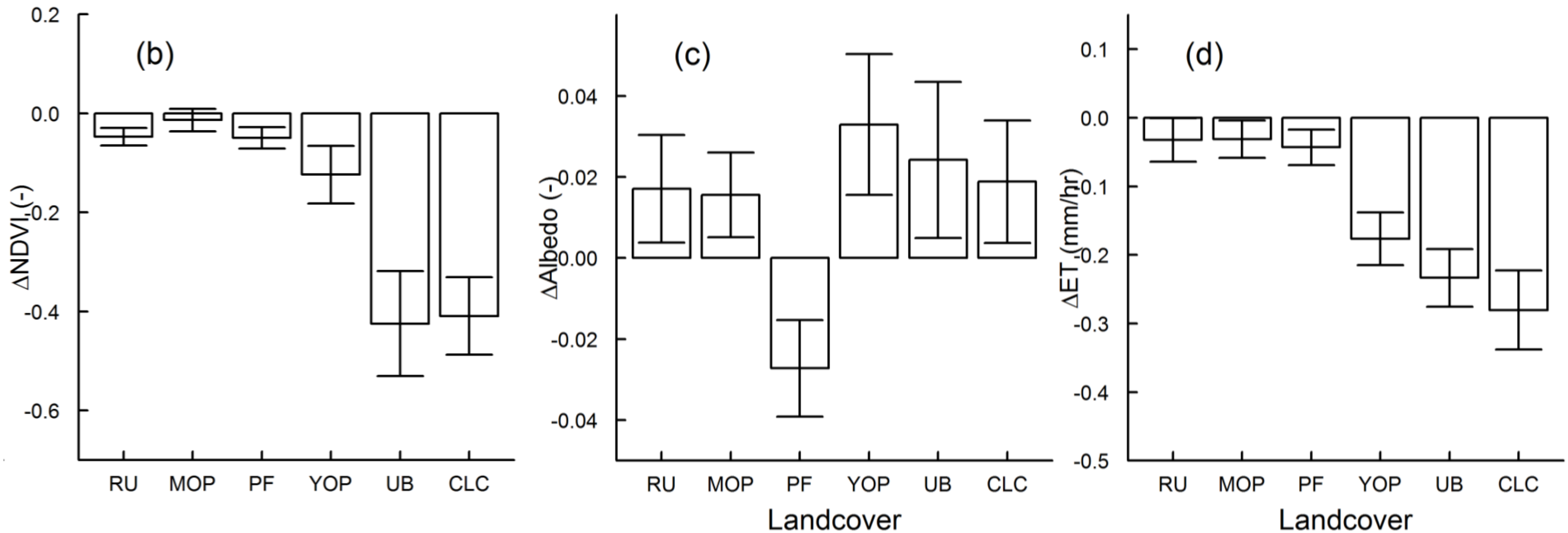
Landsat image (19-06-2013)

RU – Rubber
MOP – mature oil palm
PF – young plantation forest (mostly bare soil)
YOP – younger oil palm
UB – Urban
CLC – Clear cut

- Land-use changes from forest to other land uses have increase surface temperatures
- Mechanisms?

Sabajo et al., 2017

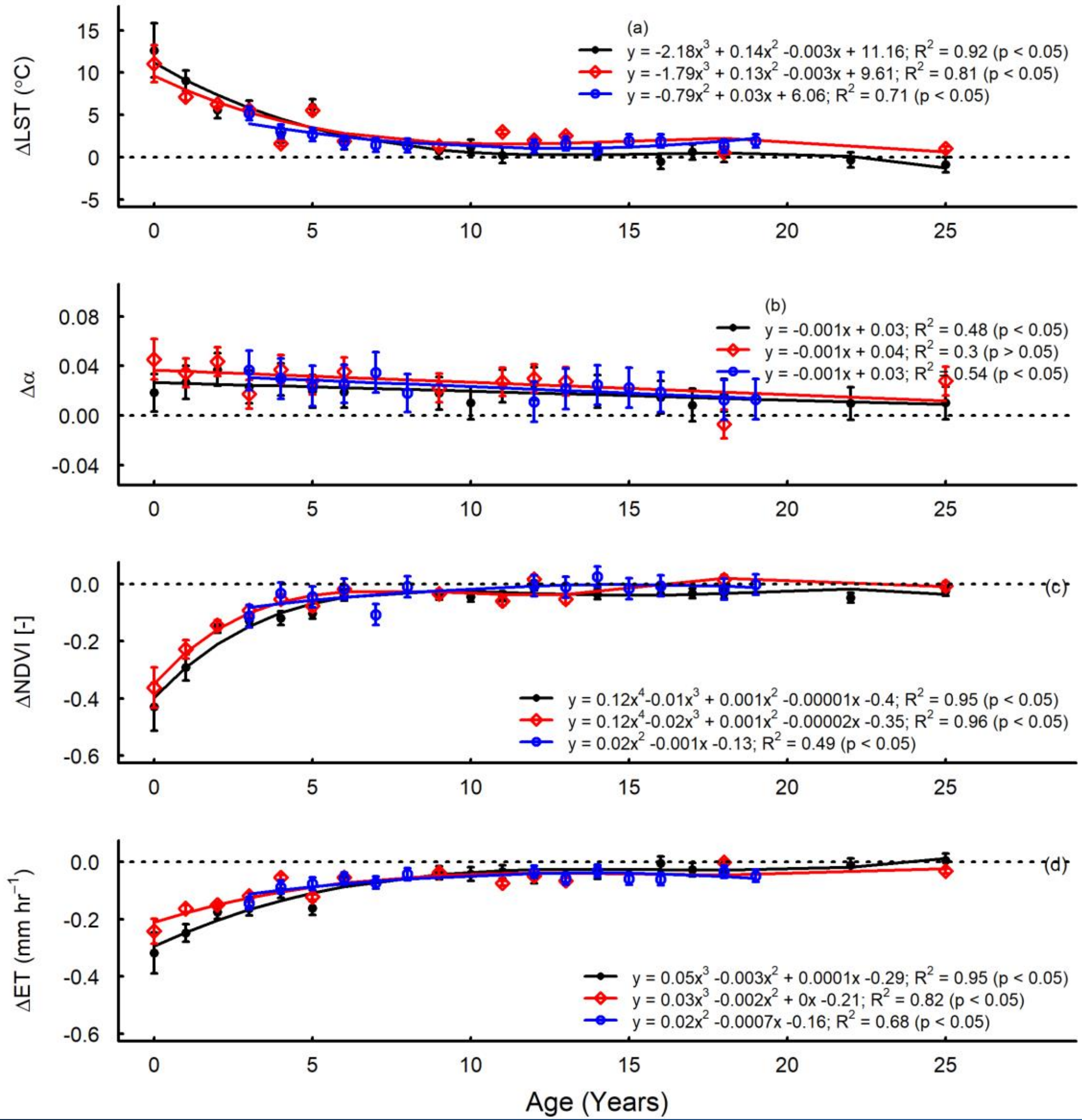
Mechanisms



- Land-use change leads to lower NDVI (less vegetation) and thus less evapotranspiration (ET)
- Evapotranspiration effect dominates over albedo effect

Sabajo et al., 2017

Surface temperature and age

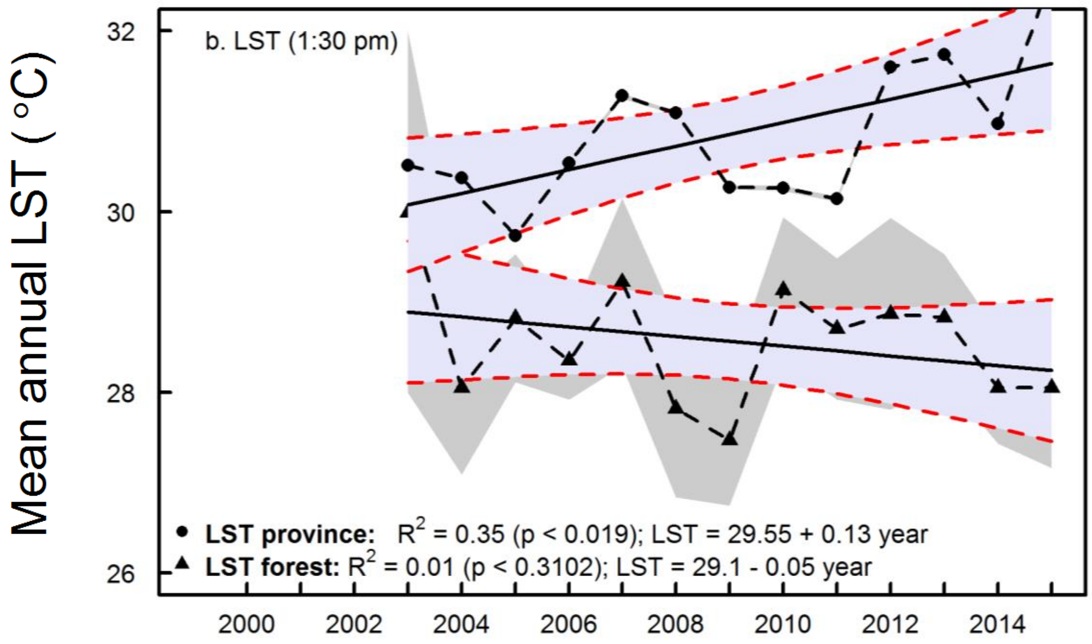


← forest as reference

- Surface temperature is a function of oil palm plantation age
- Young plantation are much hotter than forests, while mature plantation are similar to forests

Sabajo et al., unpubl.

Warming at provincial level



- The whole province is warming (0.13 °C yr^{-1} is upper boundary as it reflects clear sky days in the early afternoon)
- Forest as reference are not warming indicating that this is a land-use change effect

Sabajo et al., 2017

Summary

- Dramatic losses of biodiversity and stored carbon, but increased socio-economic benefits
- Young oil palm plantation have high CO_2 emission, mature plantation high CO_2 uptake. When yield is considered they are both clear C sources. GHG budget dominated by CO_2.
- Incorporation of measured emissions on LCA shows only 36% emission reduction in biodiesel compared to fossil fuels (not the required 60%)
- Lower vegetation cover in young oil palm plantation and clear cuts leads to lower evapotranspiration and thus higher surface temperature (up to 5°C) compared to forest
- Land-use changes lead to an increase in surface temperature at provincial level

Thanks to the Bioclimatology team and all colleagues within EFForTS









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DFG Deutsche Forschungsgemeinschaft

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