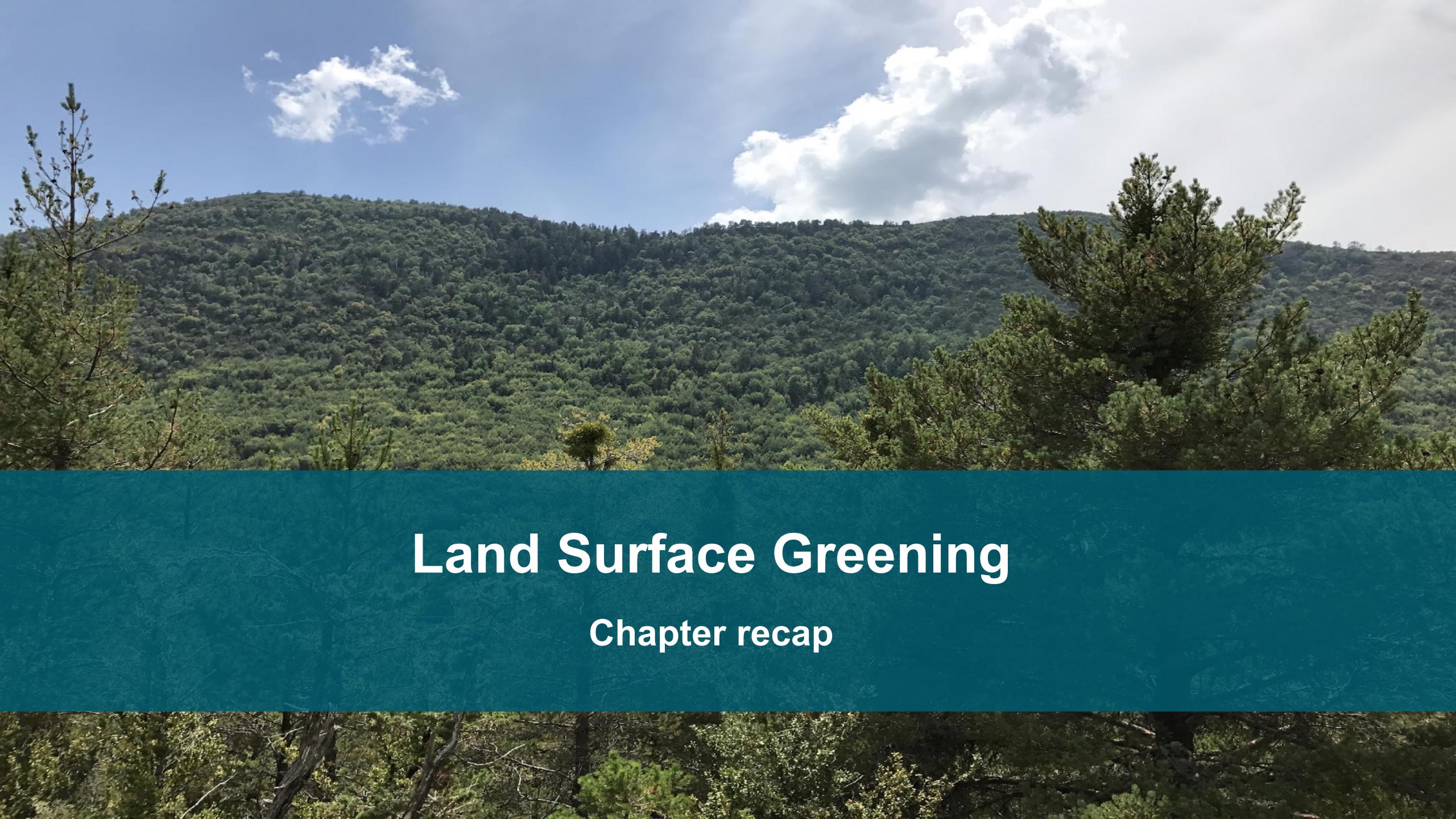


Session 09.12.2024

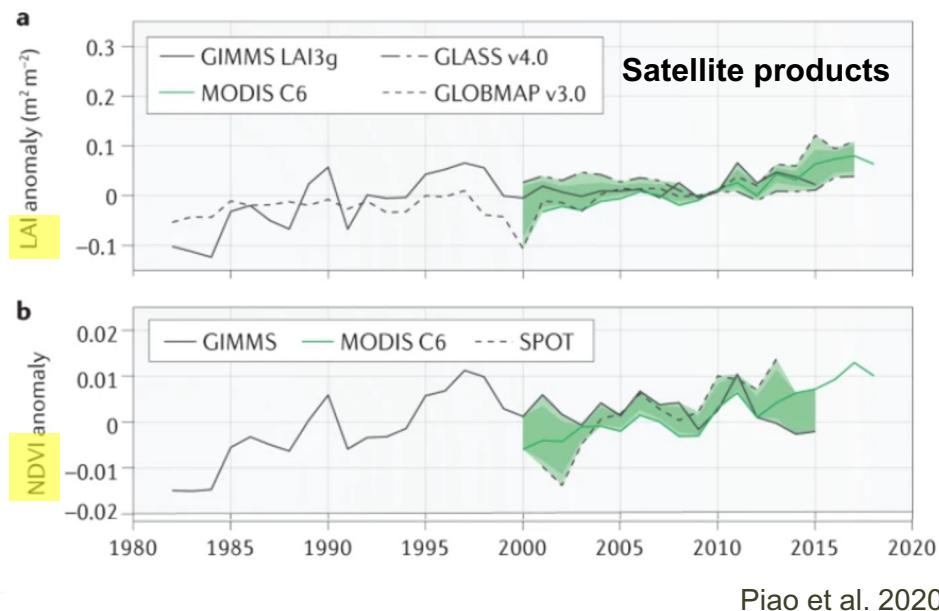
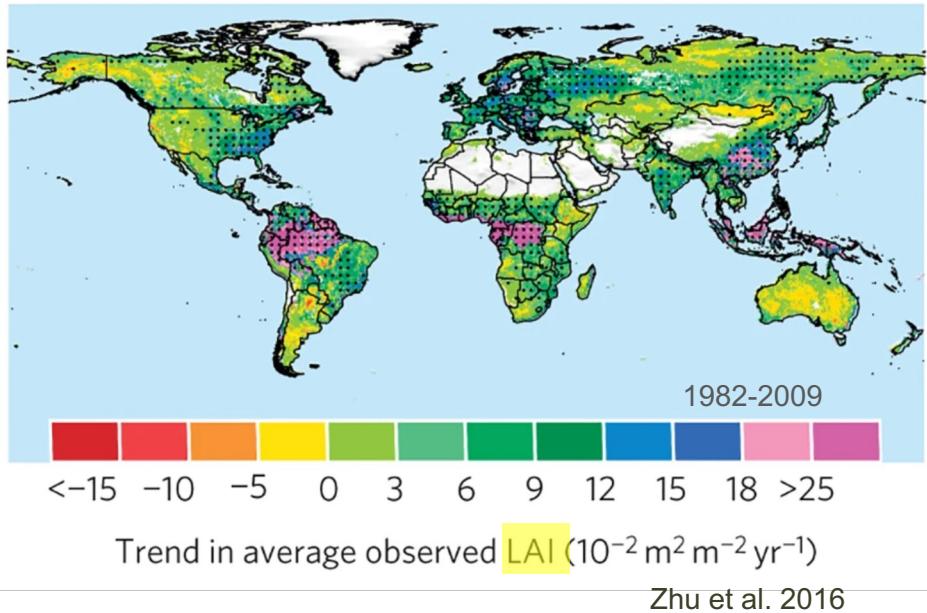
- Recap on the Land Surface Greening chapter
- Lecture: Ocean C uptake and CO₂ trajectories
- Q&A

The background of the slide is a photograph of a lush green hillside covered in dense vegetation. The sky above is a clear blue with scattered white clouds. In the foreground, the dark green branches and needles of several pine trees are visible, framing the central text area.

Land Surface Greening

Chapter recap

1. What is global greening and how is it detected?



Vegetation indices:

Leaf Area Index

$$\text{LAI} = \frac{\text{Total leaf area}}{\text{Ground area}}$$

Normalized Difference Veg Index

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

Enhance Veg Index (EVI)

Near-Infrared Reflectance (NIRv)

Fraction of absorbed PAR (fAPAR)

...

Satellite sensors:

Advanced Very-High Resolution Radiometer

AVHRR (1981–)

Vegetation (SPOT) (1998–2014)

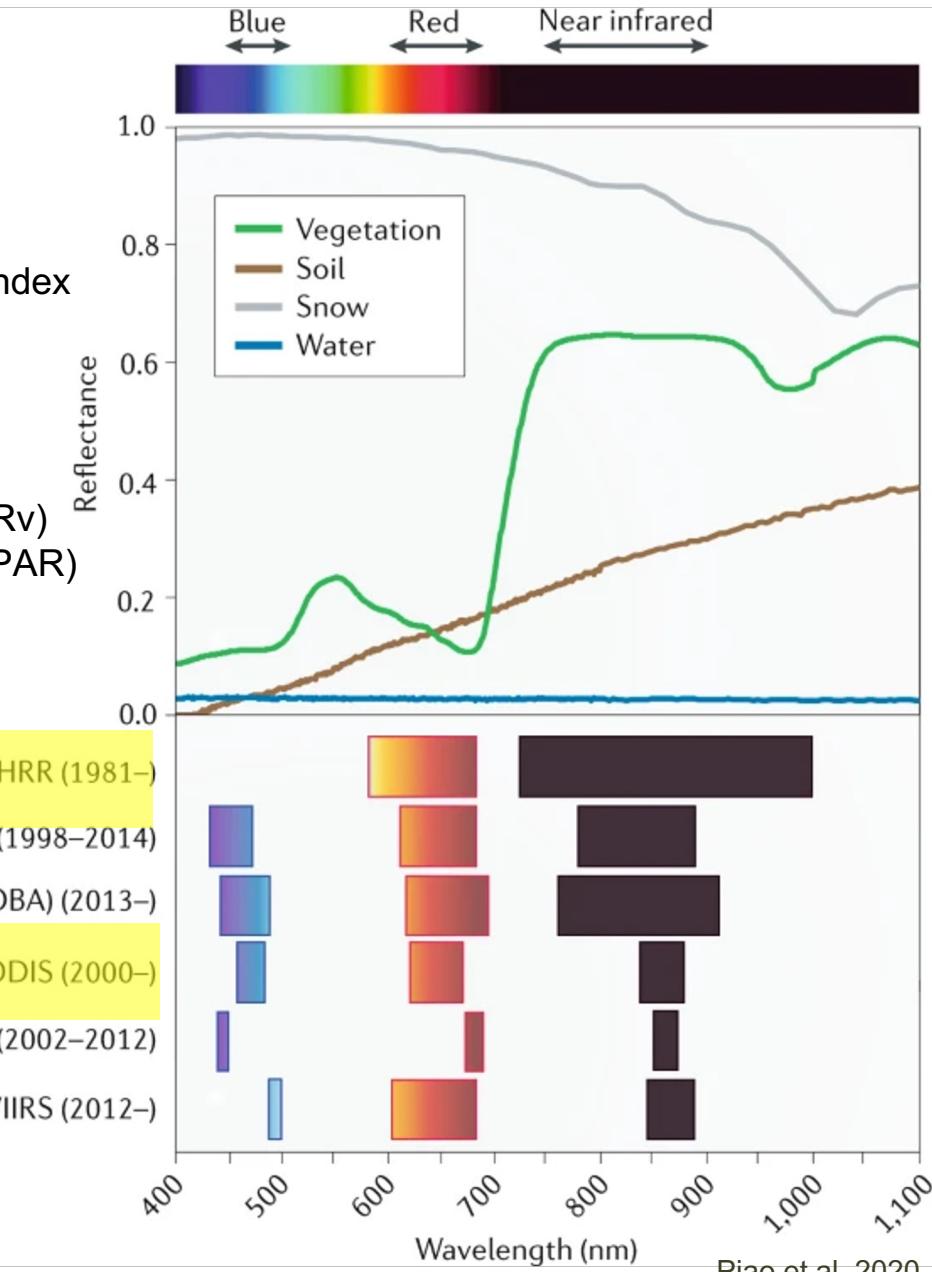
Vegetation (PROBA) (2013–)

Moderate Resolution Imaging Spectroradiometer

MODIS (2000–)

MERIS (2002–2012)

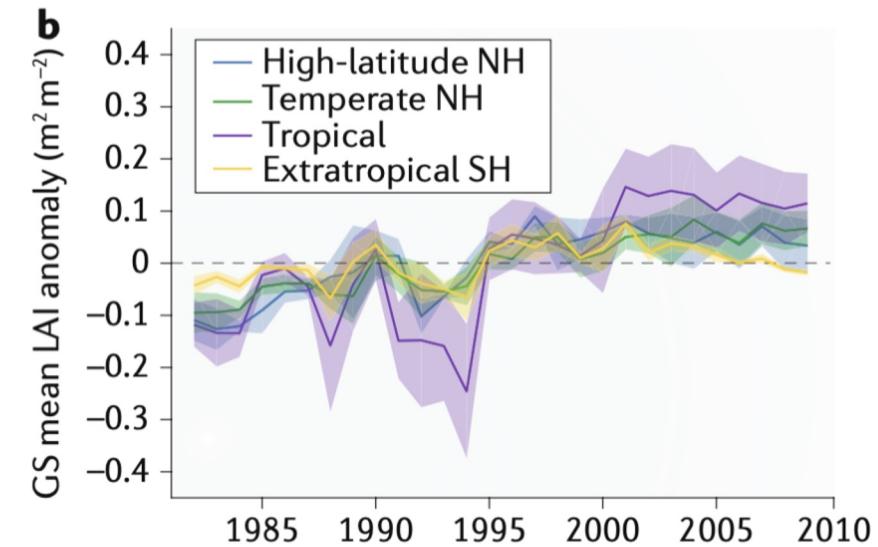
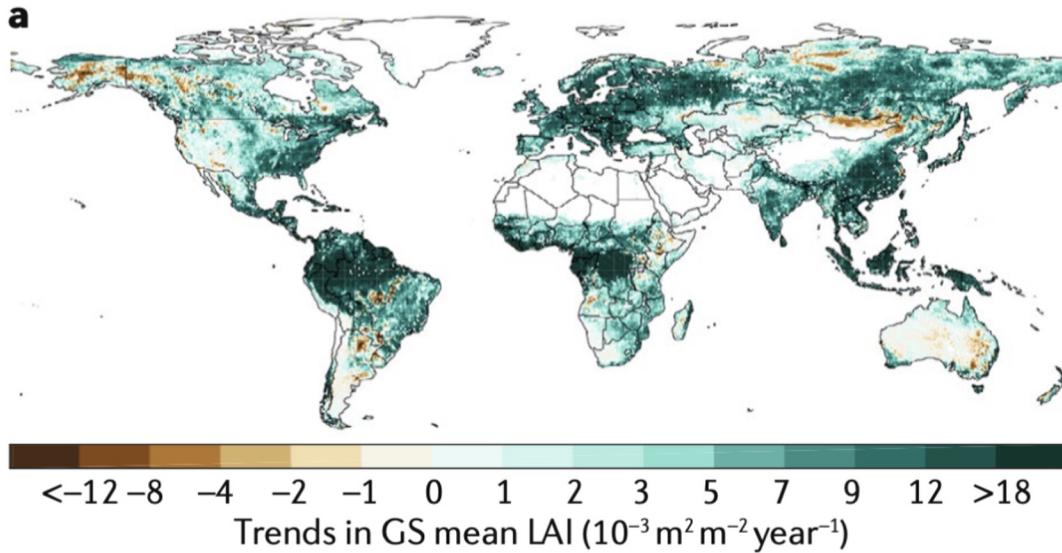
VIIRS (2012–)



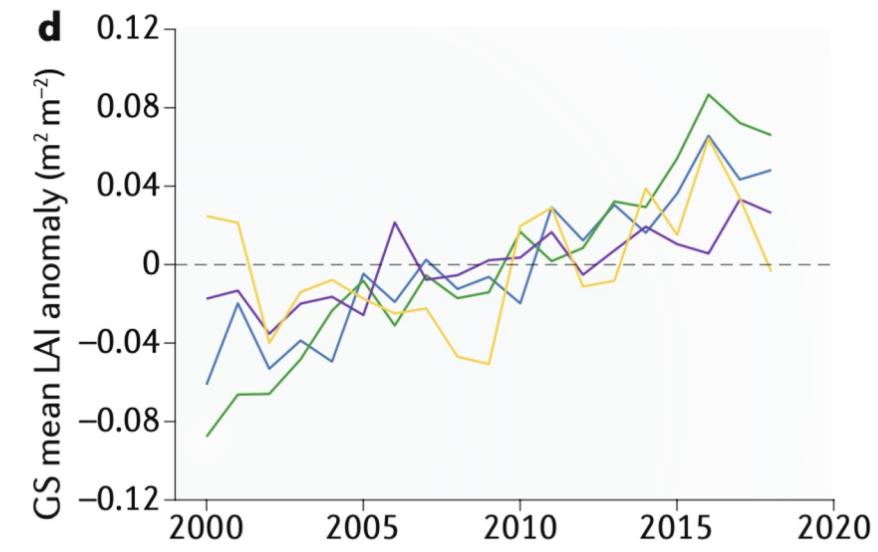
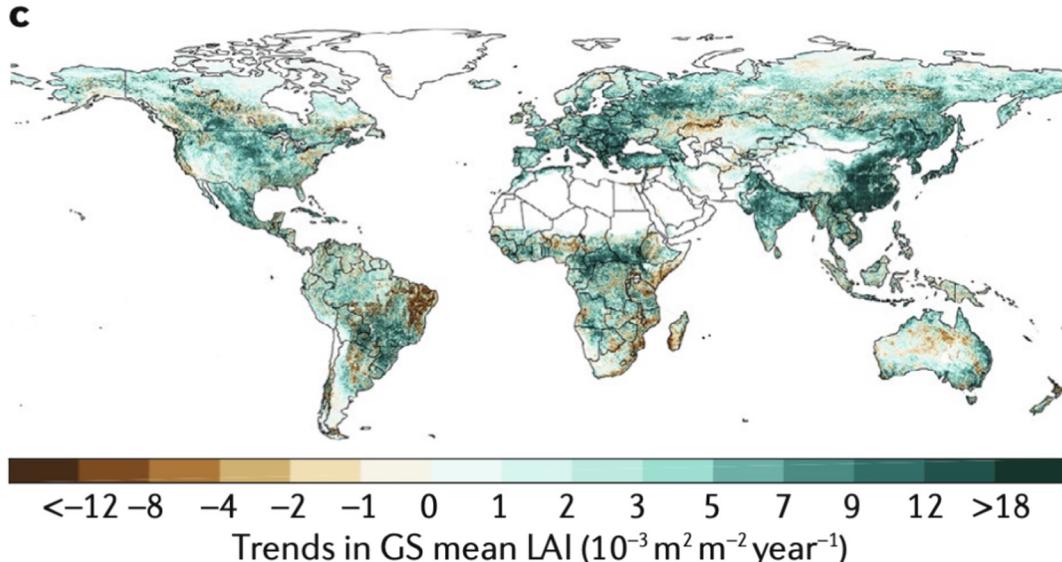
2. Greening of the Earth

Changing trends since the 2000s

1982–2009 (GIMMS, GLOBMAP and GLASS mean)



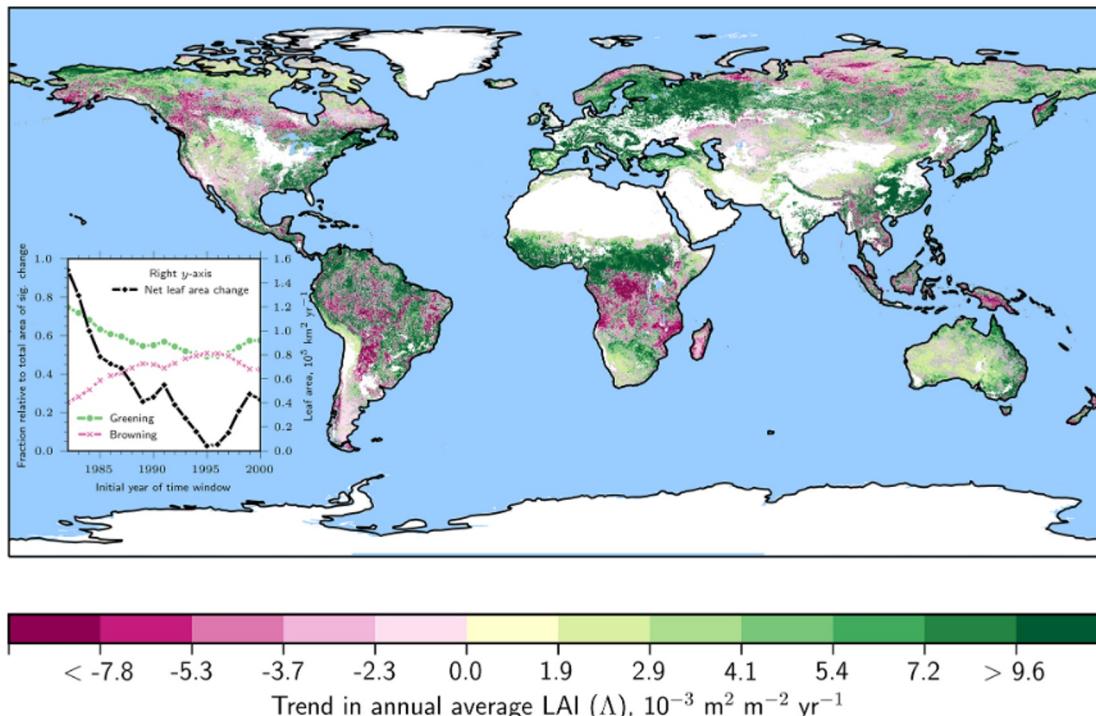
2000–2018 (MODIS)



2. Greening of the Earth

Inconsistent trends from different sensors/products

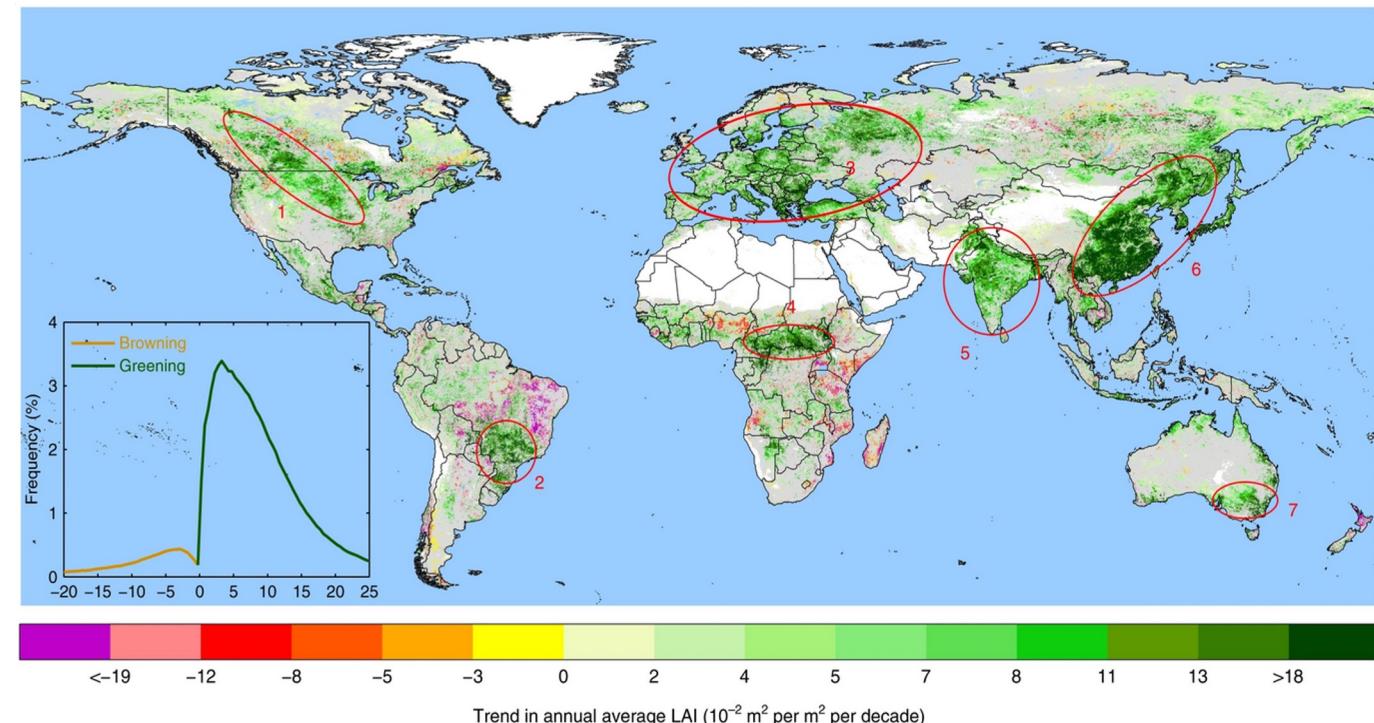
GIMMS-LAI3g (AVHRR) 1982-2017



Winkler et al. 2021

Slowdown of the greening trend and intensification of the browning trends.

MODIS C6 2000-2017

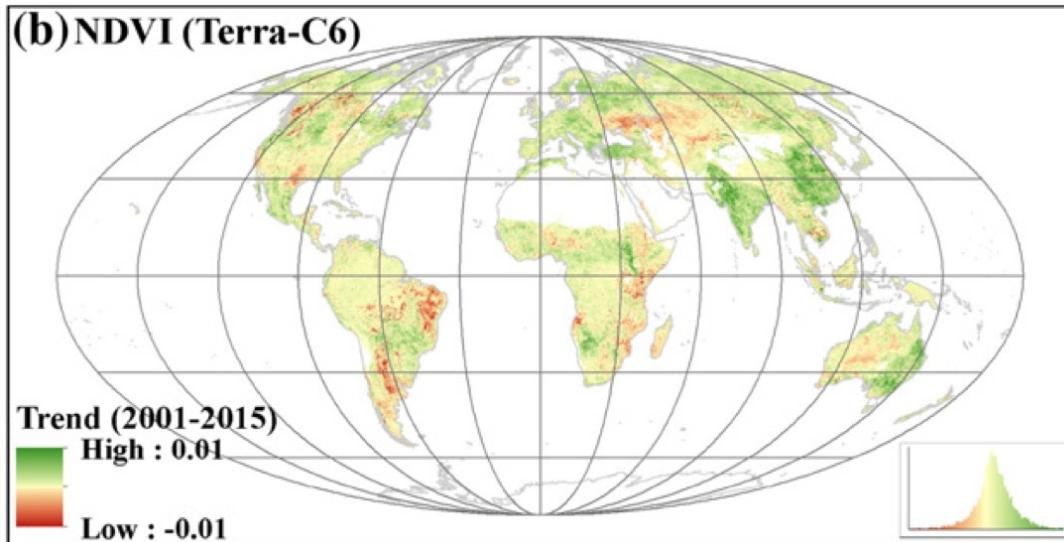
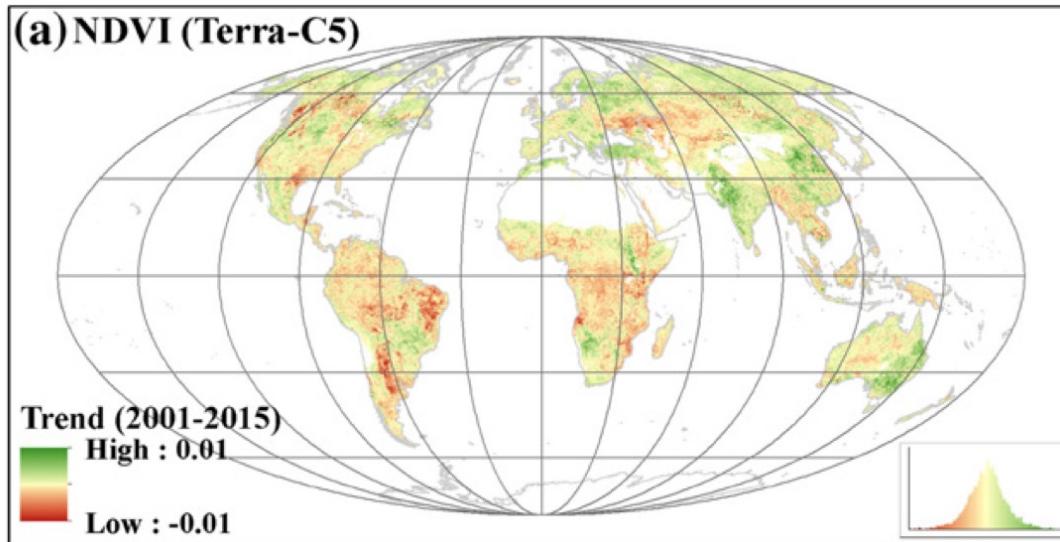


Chen et al. 2019

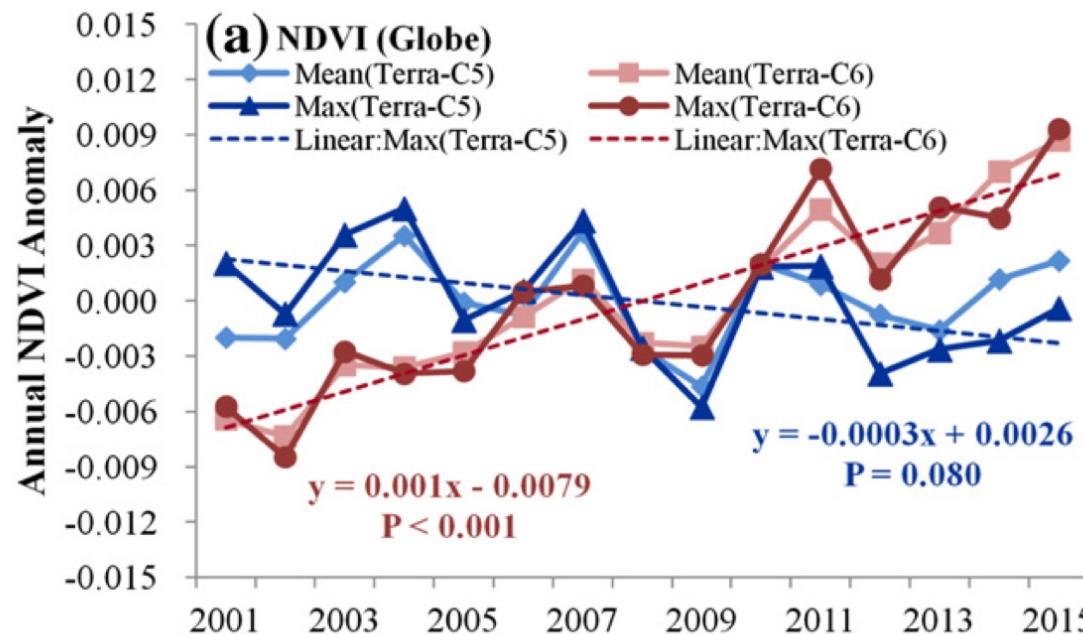
Increased of global greening and decline of browning trends.

2. Greening of the Earth

Why these Inconsistent trends? 1) Sensor degradation



Zhang et al. 2017



Interpreted as the result of sensor degradation in MODIS C5.

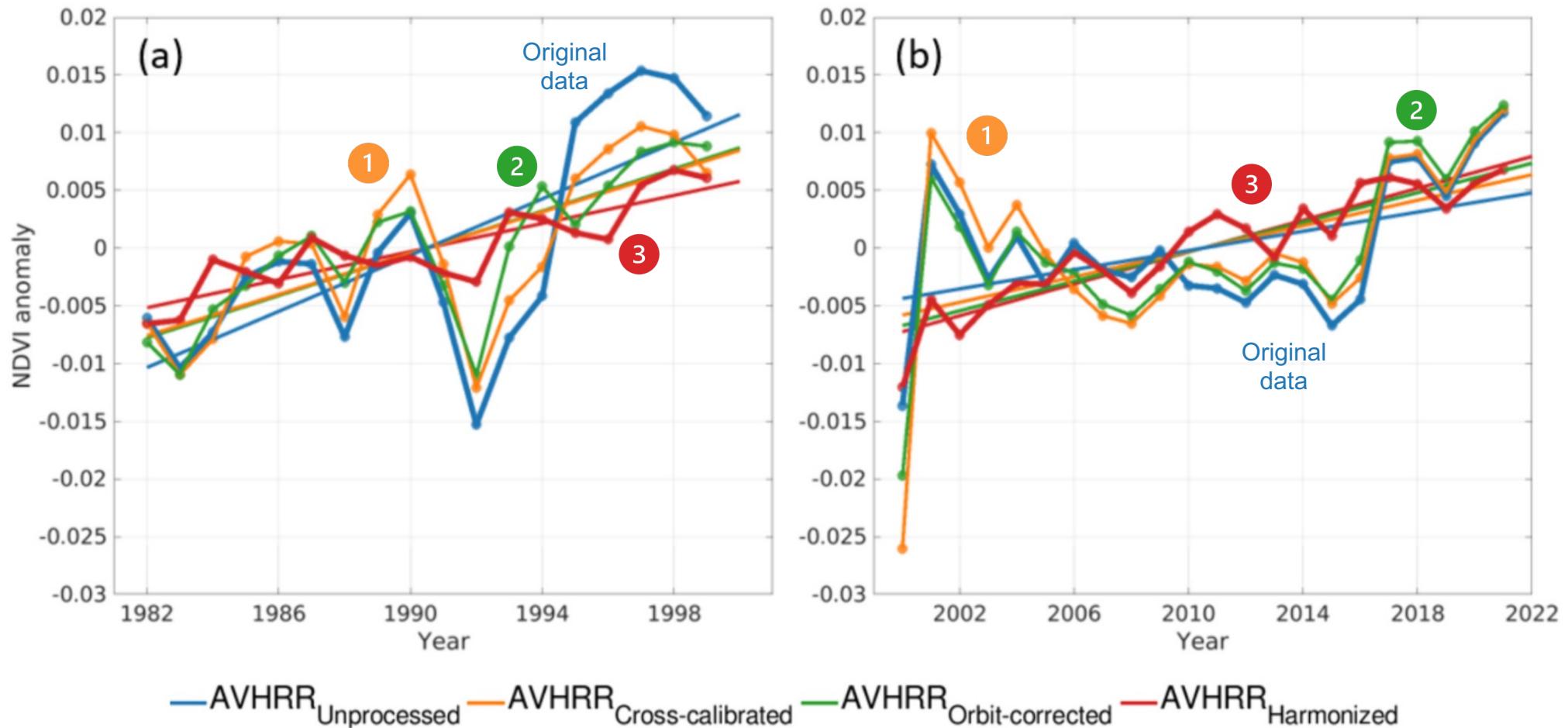
2. Greening of the Earth Why these Inconsistent trends? 2) Technical issues

1 Inconsistent biases among sensors

2 Orbital drifting

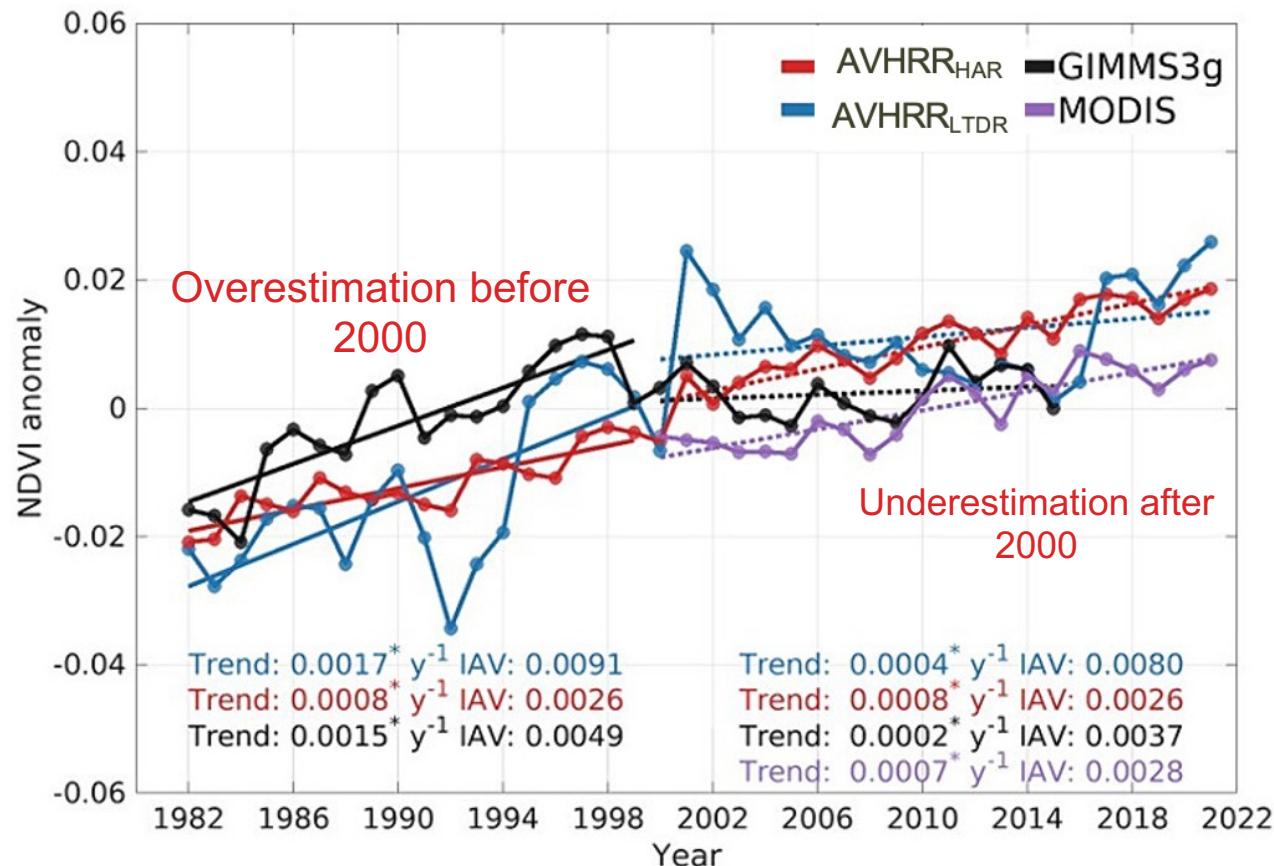
3 Incomplete harmonization of indices
(AVHRR and MODIS)

Frankenberg et al. 2021
Zhu et al. 2021



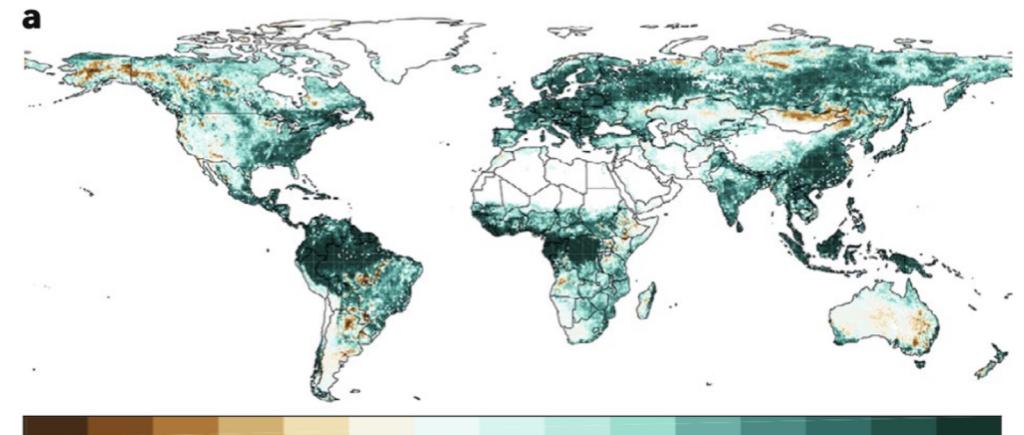
2. Greening of the Earth

Technical issues leading to artifacts

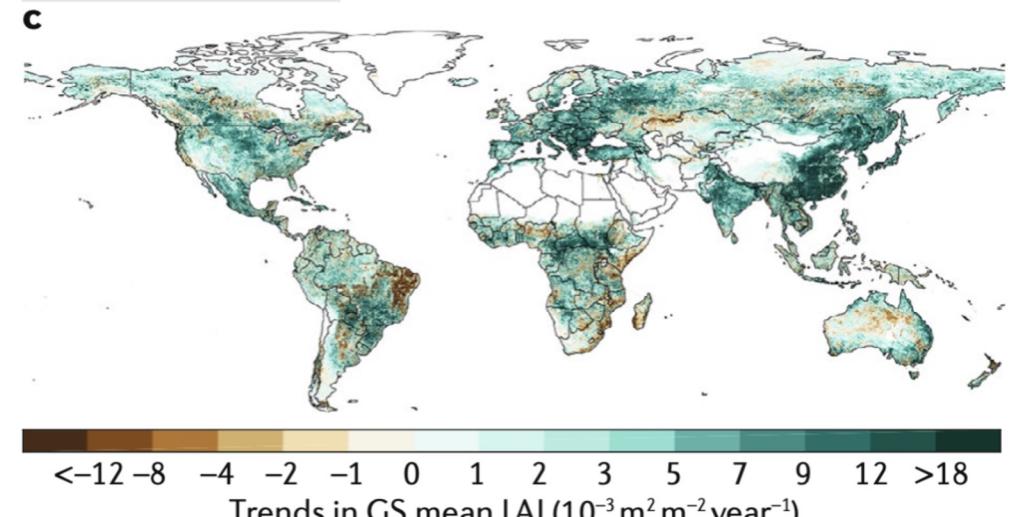


Jeong et al. 2024

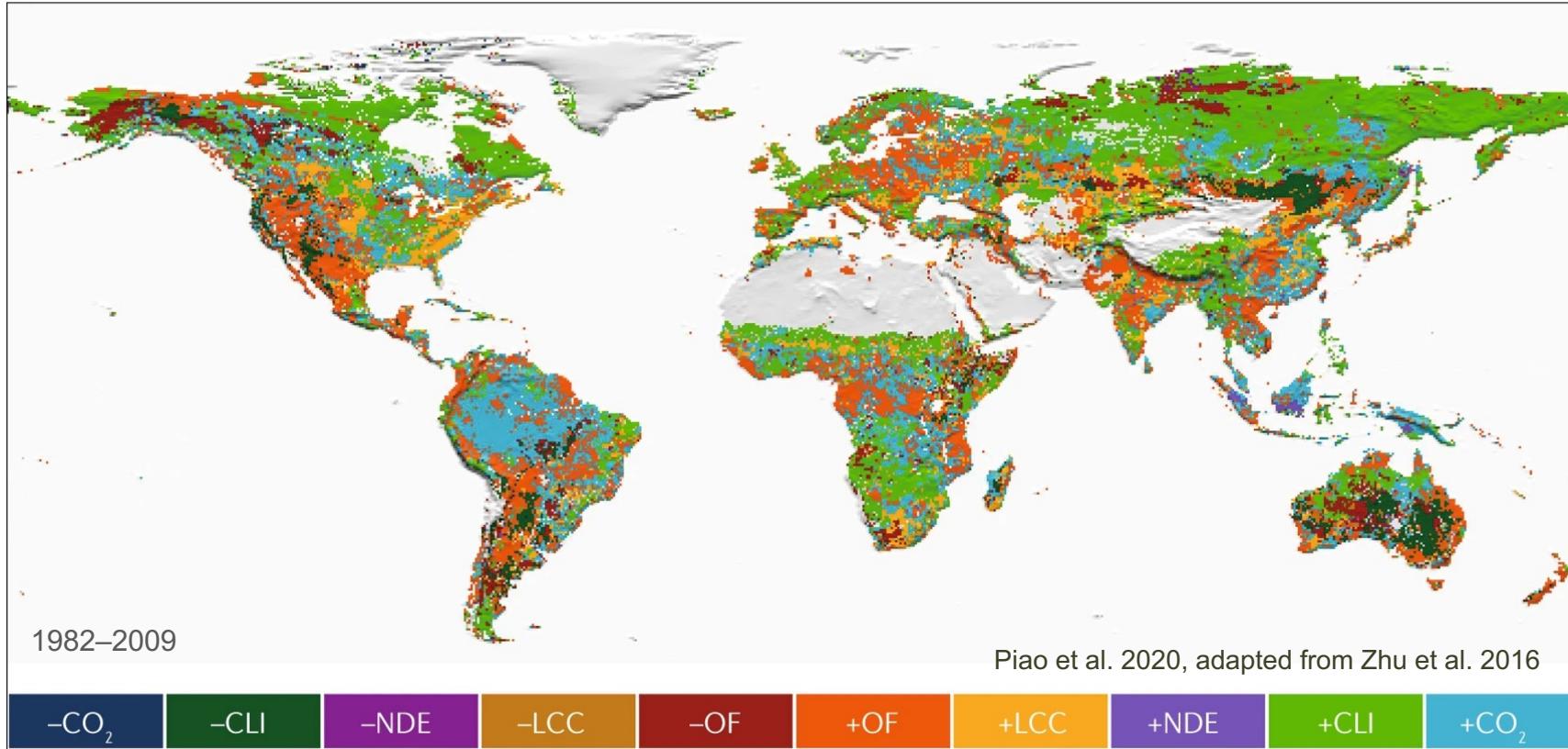
1982–2009 (GIMMS, GLOBMAP and GLASS mean)



2000–2018 (MODIS)



3. Drivers of the greening trend



CO₂ CO₂ fertilization

CLI Climate change

LCC Land cover change

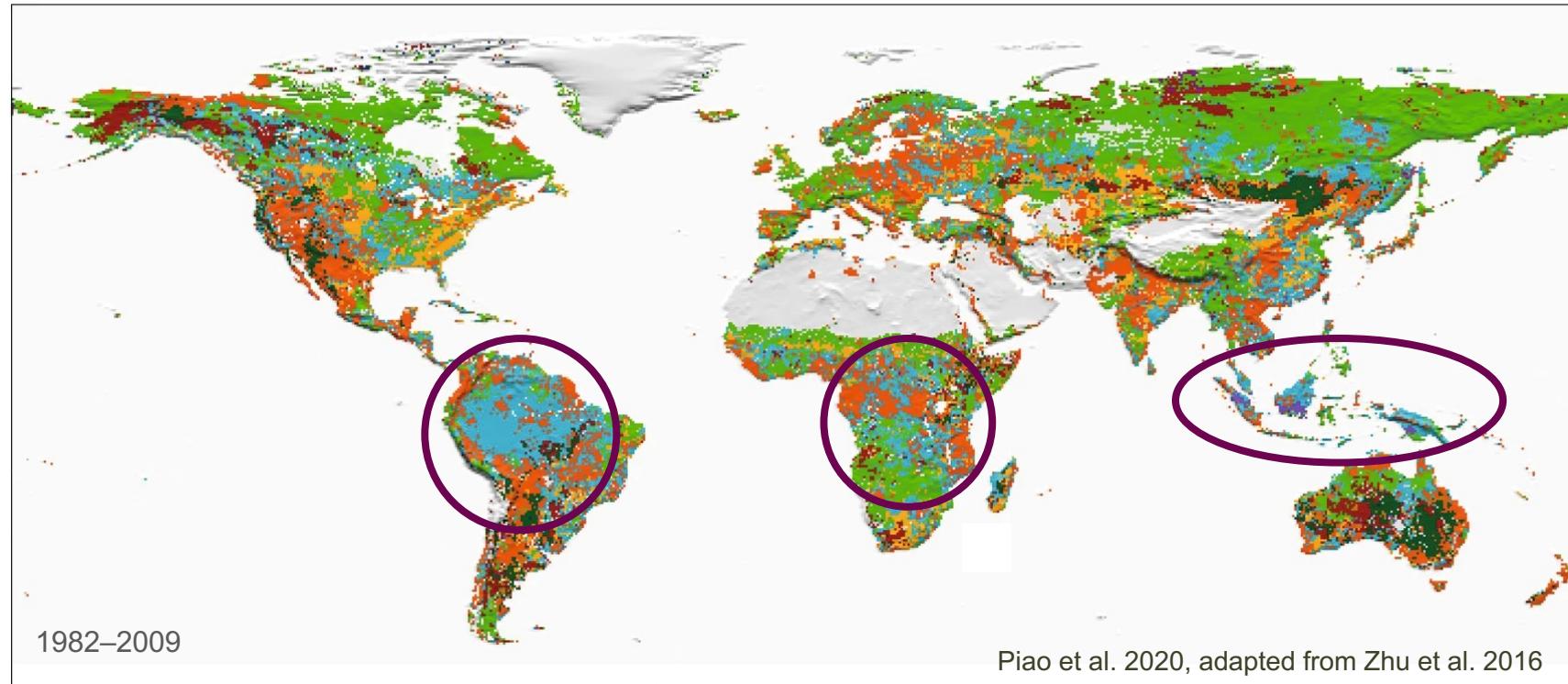
NDE Nitrogen deposition

OF Other factors

3. Drivers of the greening trend

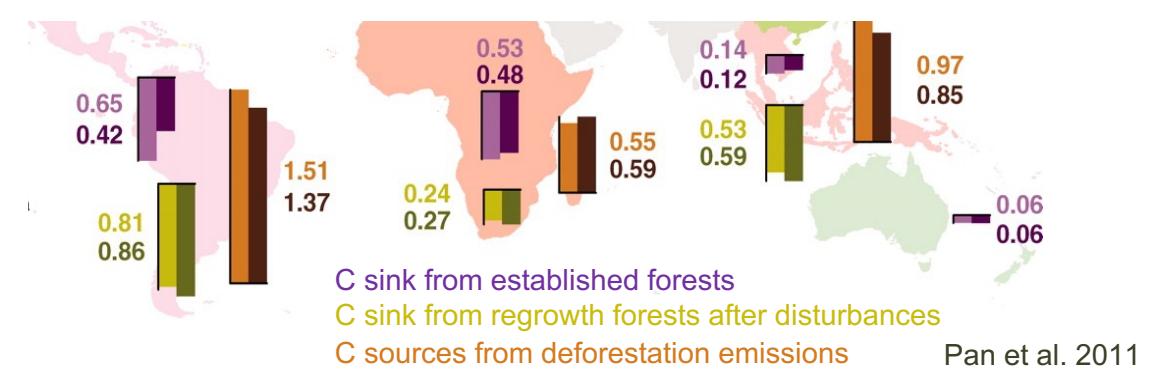
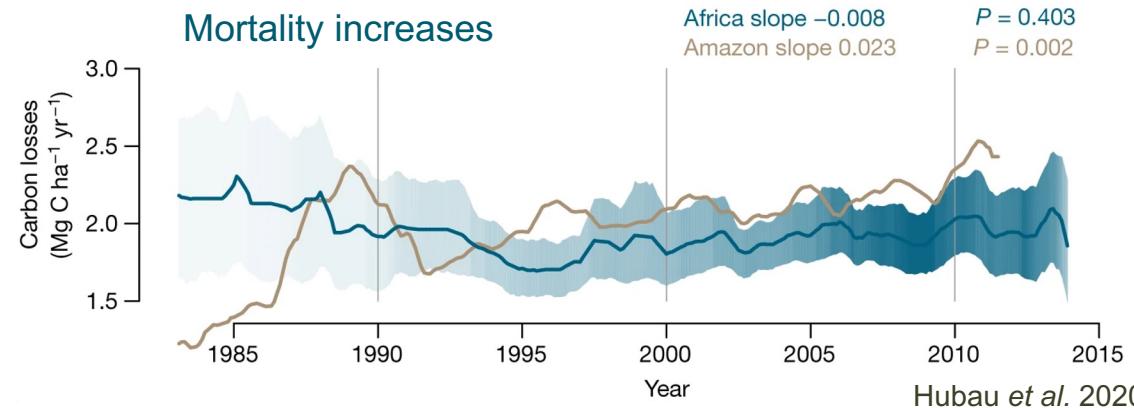
CO₂

CO₂ fertilization



In tropical regions

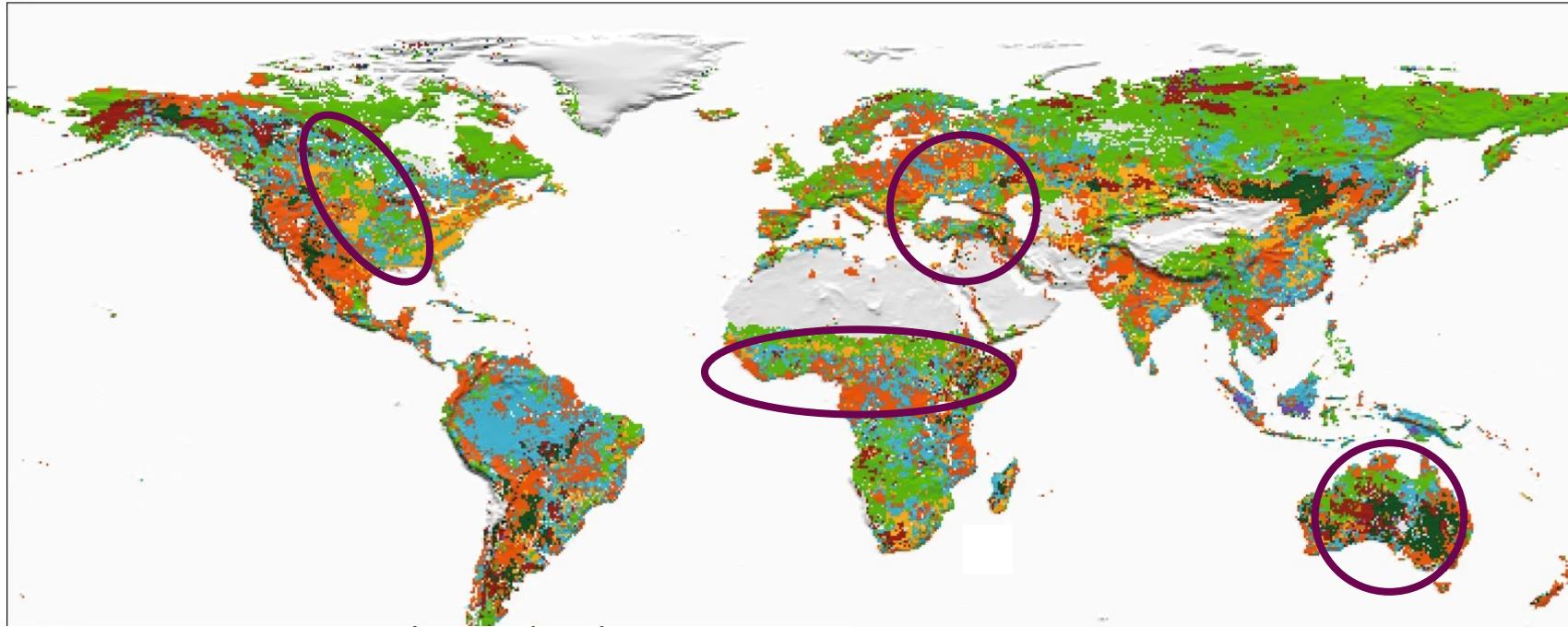
Changes in forest dynamics



3. Drivers of the greening trend

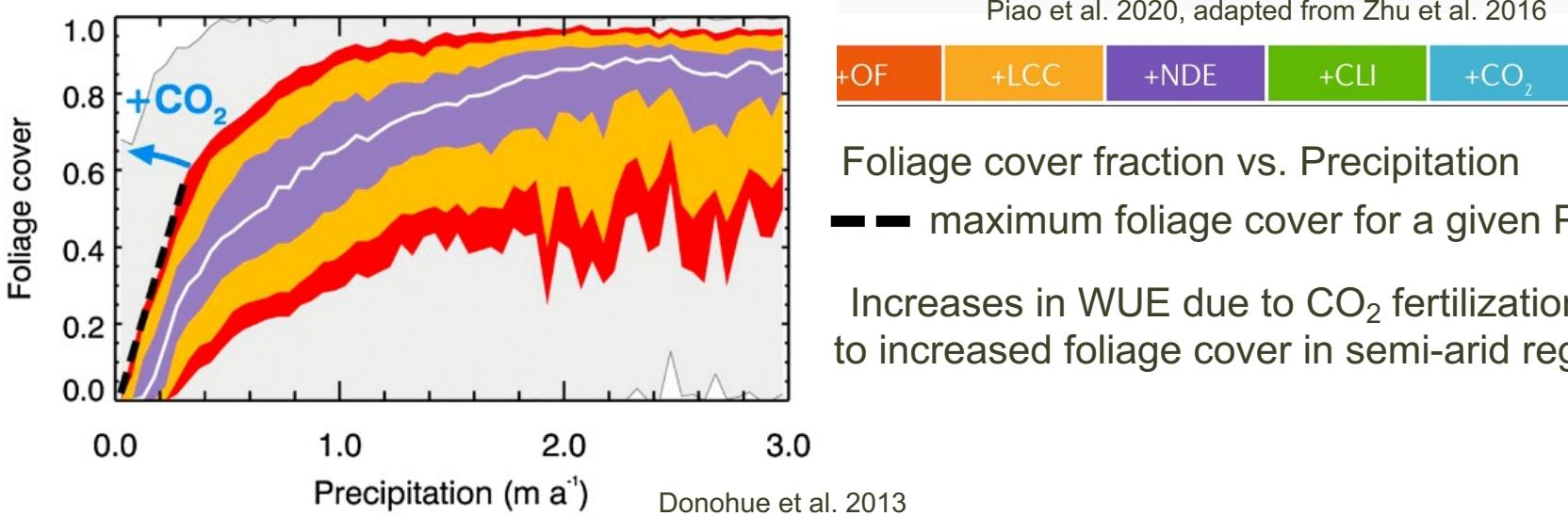
CO₂

CO₂ fertilization



In semi-arid regions

Increases in WUE

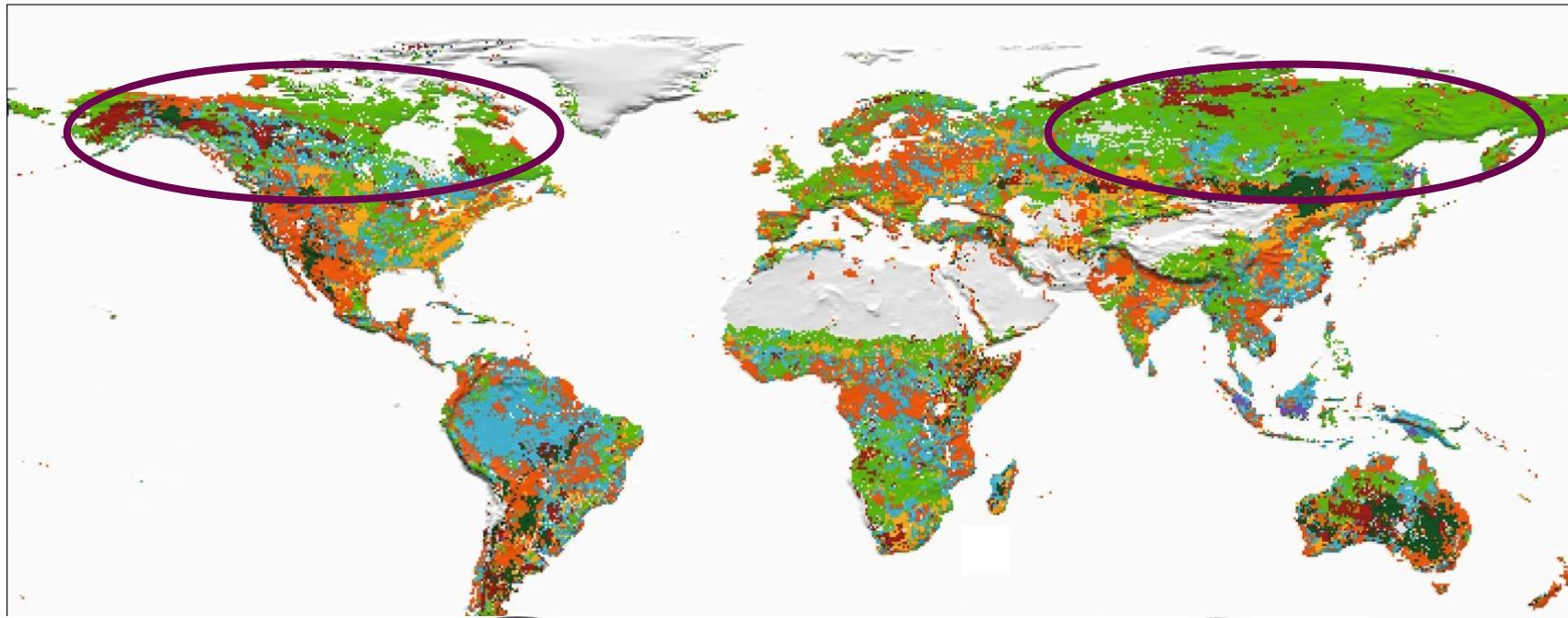


Increases in WUE due to CO₂ fertilization led to increased foliage cover in semi-arid regions.

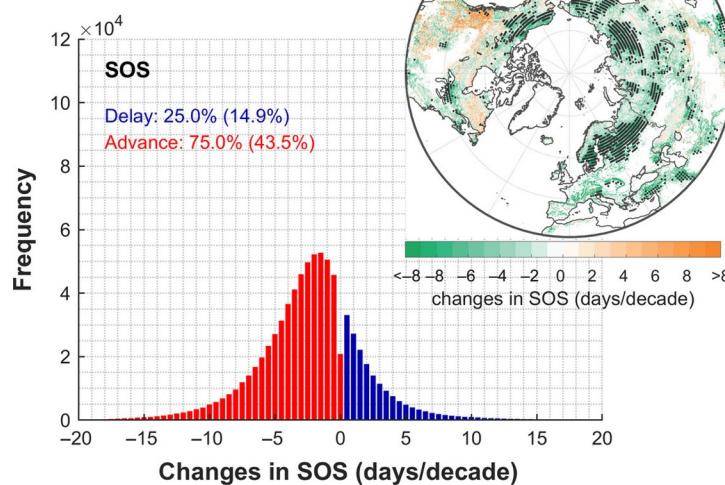
3. Drivers of the greening trend

CLI

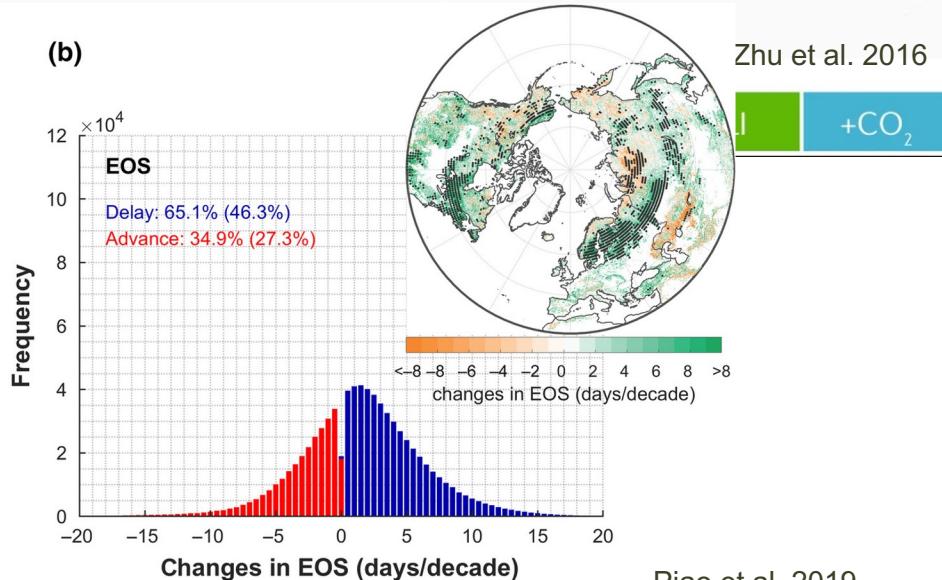
Climate Change



(a)



(b)



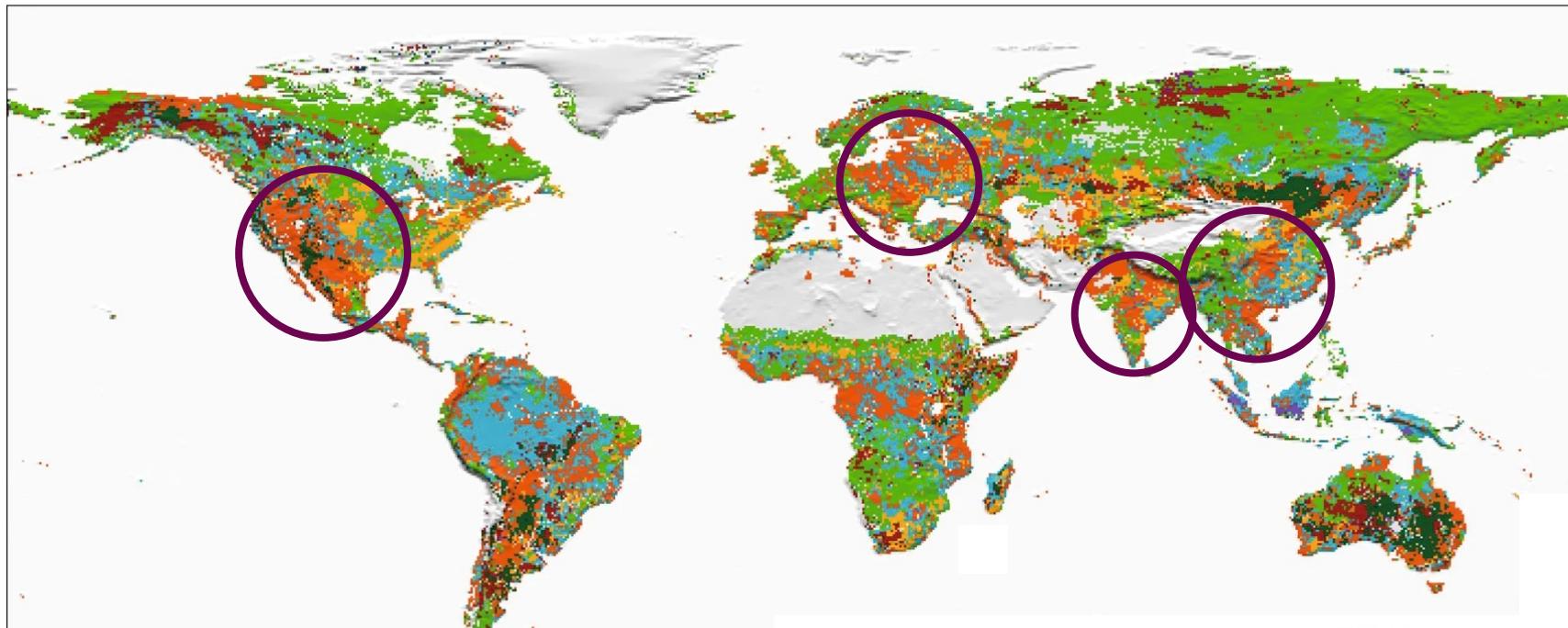
In high latitudes

Warmer temperatures
Growing season lengthening

3. Drivers of the greening trend

LCC

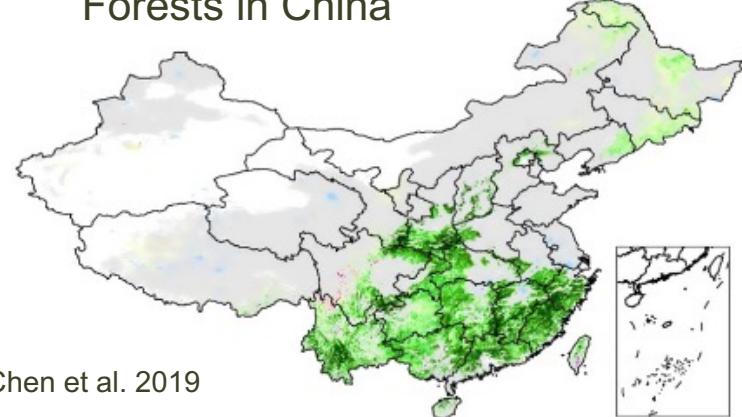
Land use change



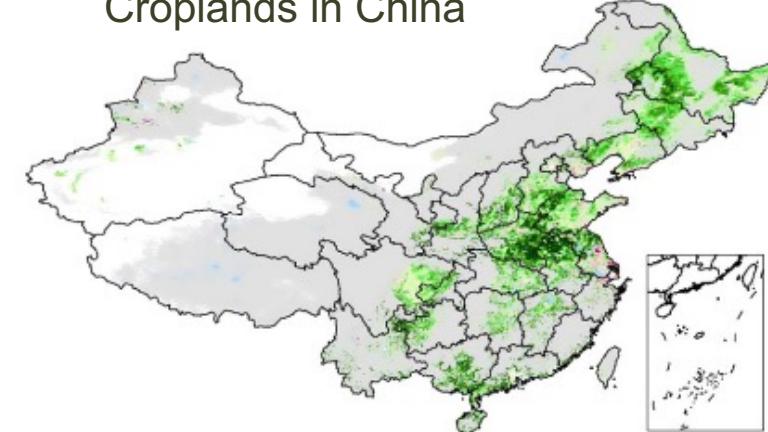
Cropping

Afforestation

Forests in China



Croplands in China

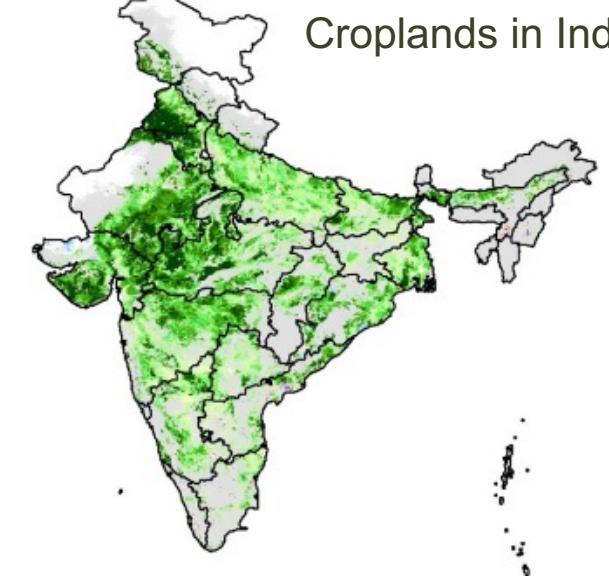


Chen et al. 2019



Trend in annual average LAI ($10^{-2} \text{ m}^2 \text{ per m}^2 \text{ per decade}$)

Croplands in India



Summary

1. What is global greening and how is it detected?

2. Greening of the Earth

Inconsistent trends from different sensors/products

Sensor degradation

Technical issues leading to artifacts

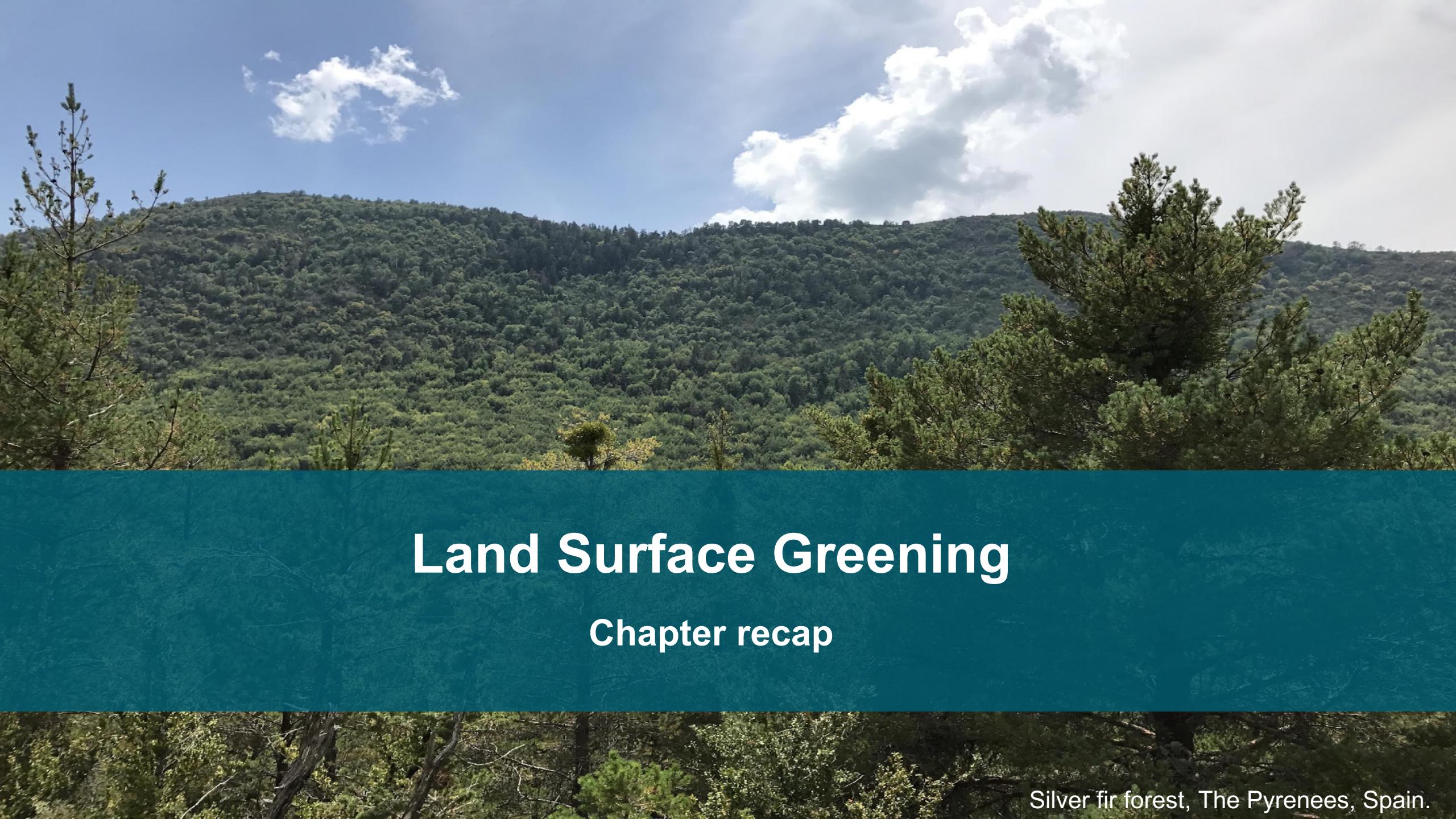
Data processes and harmonization

3. Drivers of the greening trend

CO₂ fertilization In tropical and semi-arid regions

Climate Change In Arctic and boreal regions

Land use change China and India

The background image shows a vast, green forest covering rolling hills under a bright blue sky dotted with fluffy white clouds. In the foreground, the dark green branches and needles of a silver fir tree are visible.

Land Surface Greening

Chapter recap

Silver fir forest, The Pyrenees, Spain.