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Forest Resilience, Precipitation, and Ecosystem Service Value: A Correlation and Trend Analysis

Pius Nwachukwu (1) and Laure Berti-Equille (1)

1. IRD, UMR ESPACE DEV, France

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https://www.eco2adapt.eu/

Outline

Context

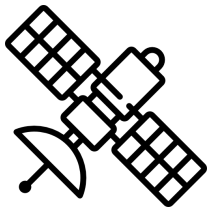
Forest Ecosystem Services

A forest's ecosystem services include:

- Preserving biodiversity as home to numerous species;
- Sequestering carbon and mitigating climate change;
- Conserving soil and preventing land degradation;
- Acting as water filters and preventing floods;
- Serving as places of recreation and leisure.

Source: https://www.inrae.fr/sites/default/files/r2_tomorrowforest_infography_web_1.pdf

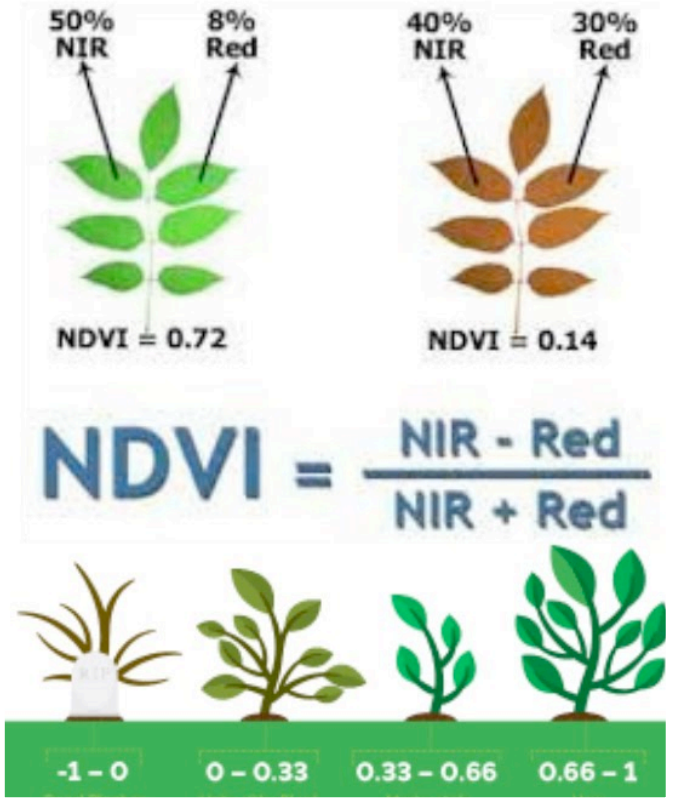
Forest Resilience from the Sky



Resilience is the ability to endure, adjust, and recover from natural disasters like wildfires, insect outbreaks, and severe climate change-induced catastrophes.

kNDVI [1,2] is used as proxy of the resilience of global forests (vegetated areas with a canopy ≥5 meters).

$$\mathrm{kNDVI} = \tanh\left(\left(\frac{\mathrm{NIR} - \mathrm{red}}{2\sigma}\right)^2\right) \quad \text{with} \quad \sigma = 0.5(\mathrm{NIR} + \mathrm{red})$$



[1] Camps-Valls, G. et al. A unified vegetation index for quantifying the terrestrial biosphere. *Sci. Adv.* **7**, eabc7447 (2021).
[2] G. Forzieri *et al.*, 'Emerging signals of declining forest resilience under climate change', *Nature*, vol. 608, no. 7923, pp. 534–539, Aug. 2022, doi: 10.1038/s41586-022- 04959-9.

Our Research Questions

1. In the last 25 years, can we observe correlations between precipitation, forest resilience and ecosystem service value (ESV)?

2. Are there differences or patterns across continents?

3. Can we predict ESV over time?

Data Collection & Processing

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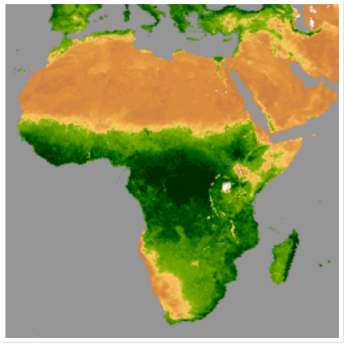
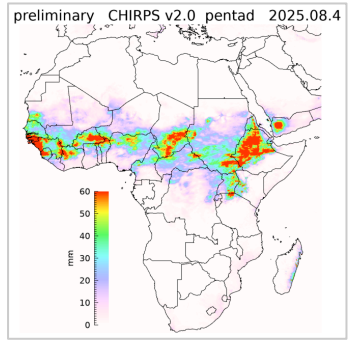
Datasets

1. MODIS13A3 V6.1 monthly satellite data 1km spatial resolution from NASA LP DAAC USGS EROS Center



https://www.earthdata.nasa.gov/data/catalog/lpcloud-mod13a3-061

2. CHIRPS (Climate Hazards group InfraRed Precipitation) monthly precipitation mean from 2000-02-01 to 2024-04-30 at a 0.05° x 0.05° resolution



https://www.chc.ucsb.edu/data/chirps

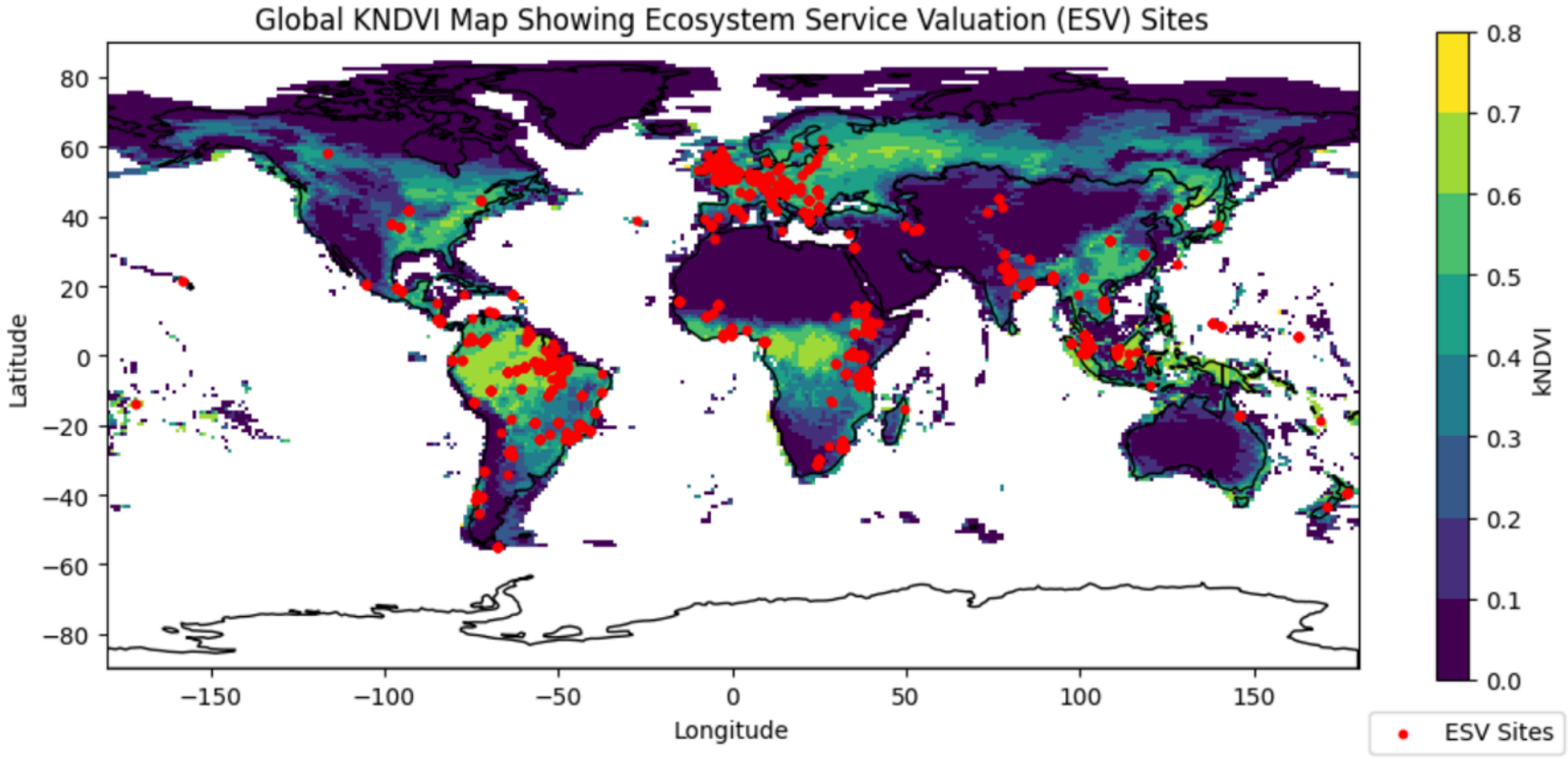
3. Ecosystem Services Valuation Database (ESVD)

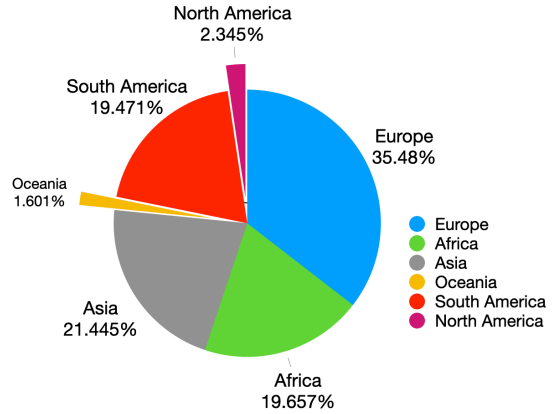
ESVD
ECOSYSTEM SERVICES VALUATION DATABASE

https://www.esvd.net

Filtering

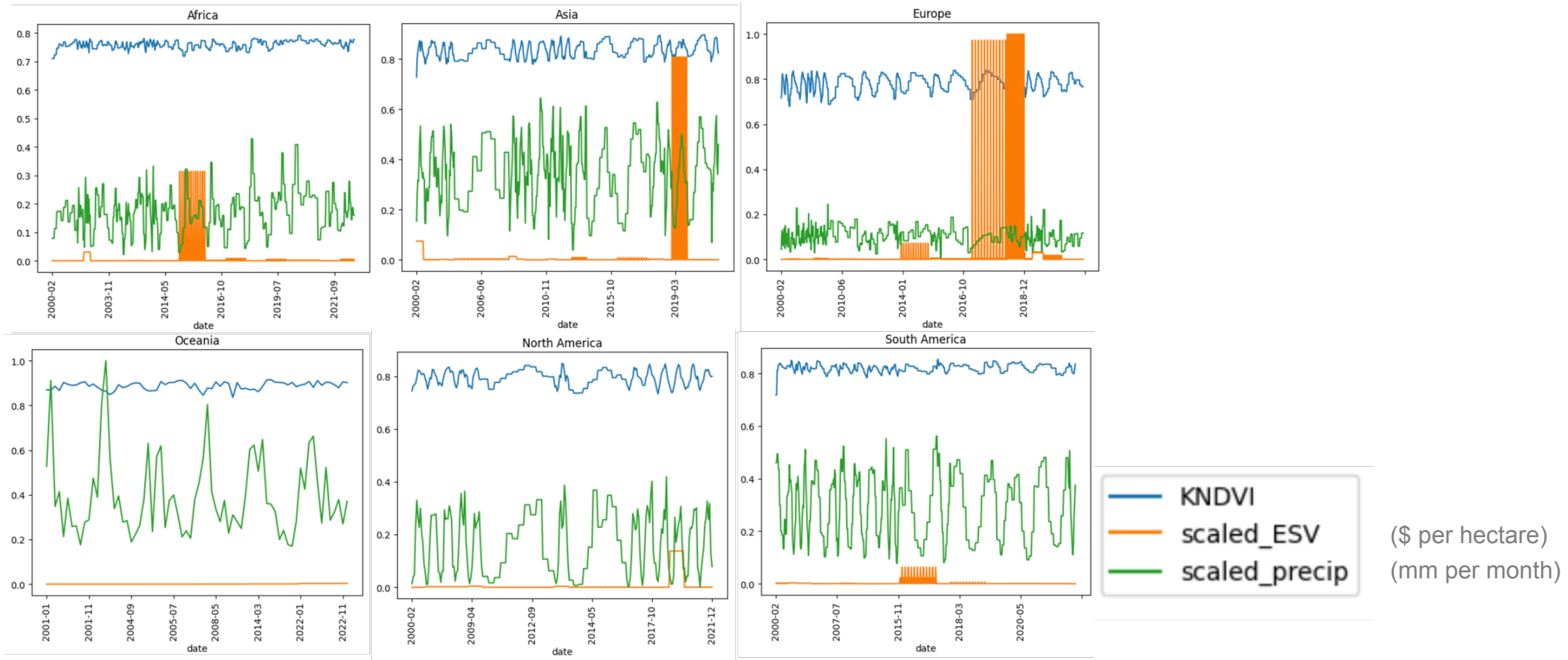
We considered 2,801 ESV sites in forest areas.





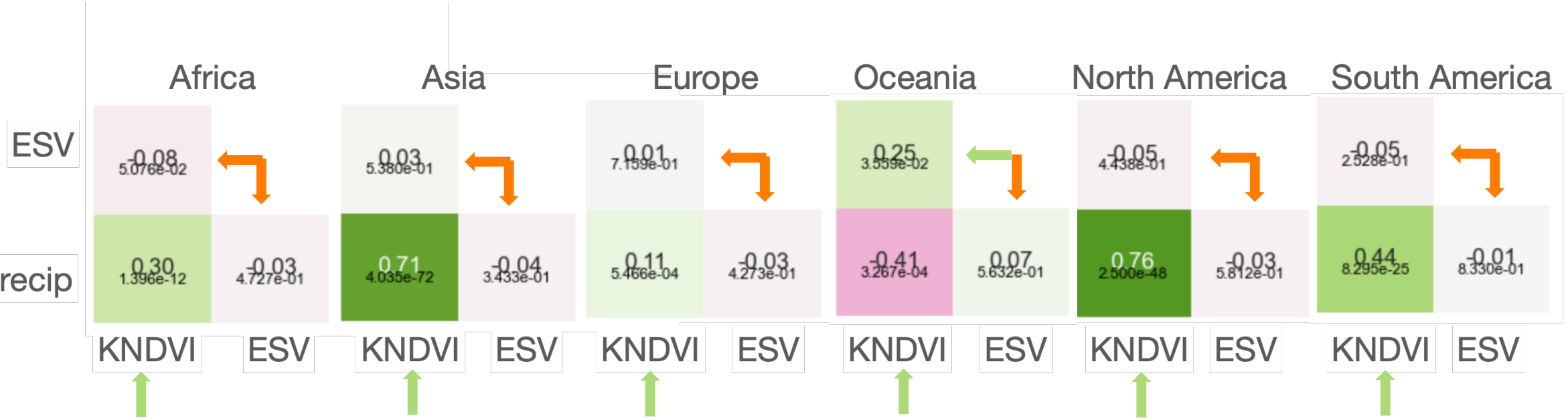
	Nb of ESV sites
Europe	953
Asia	576
Africa	528
South America	523
North America	63
Oceania	43

Rescaling – Time Series Visualization



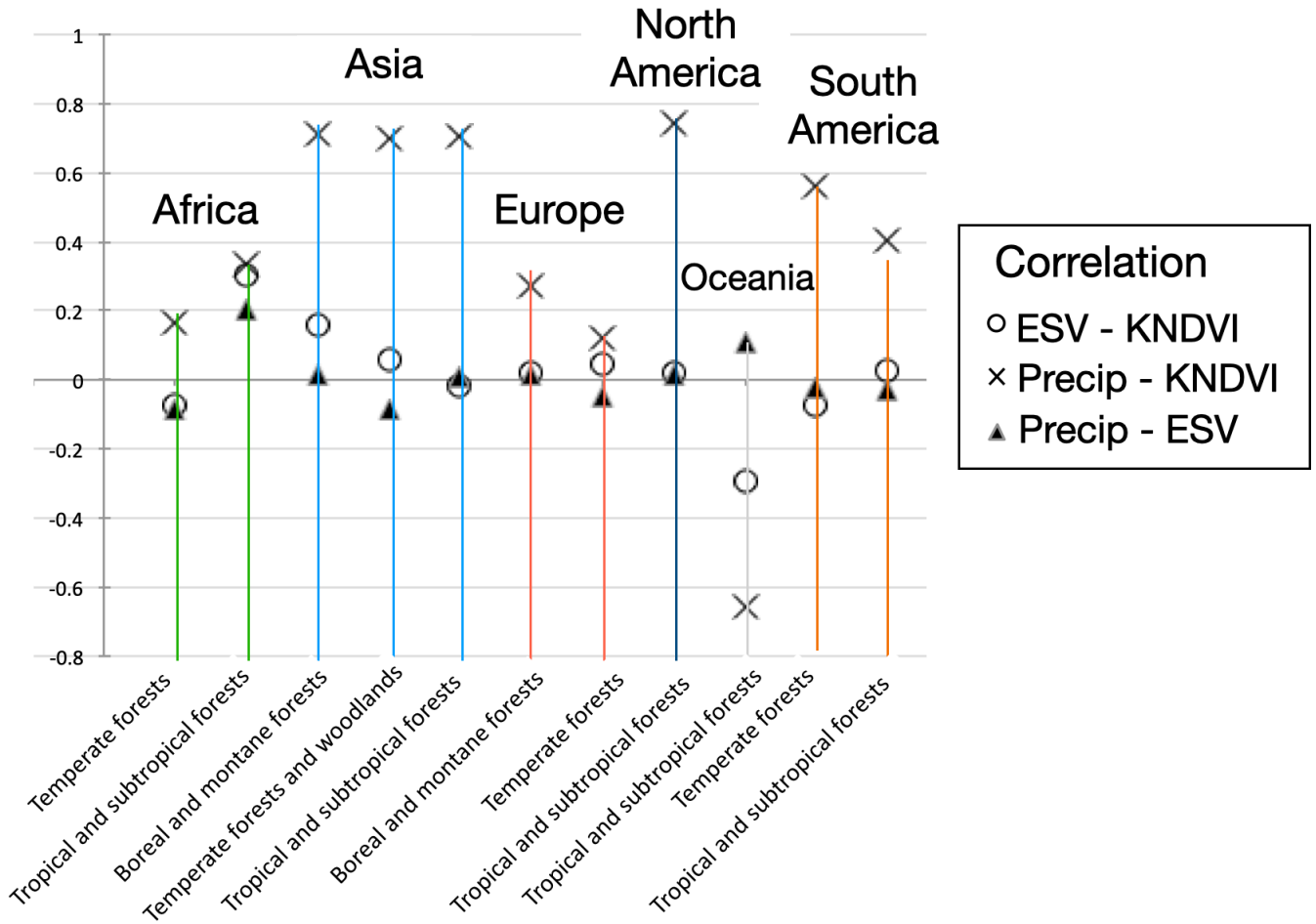
Analysis & Results

ESV-kNDVI-Precipitation Correlations (1/2)



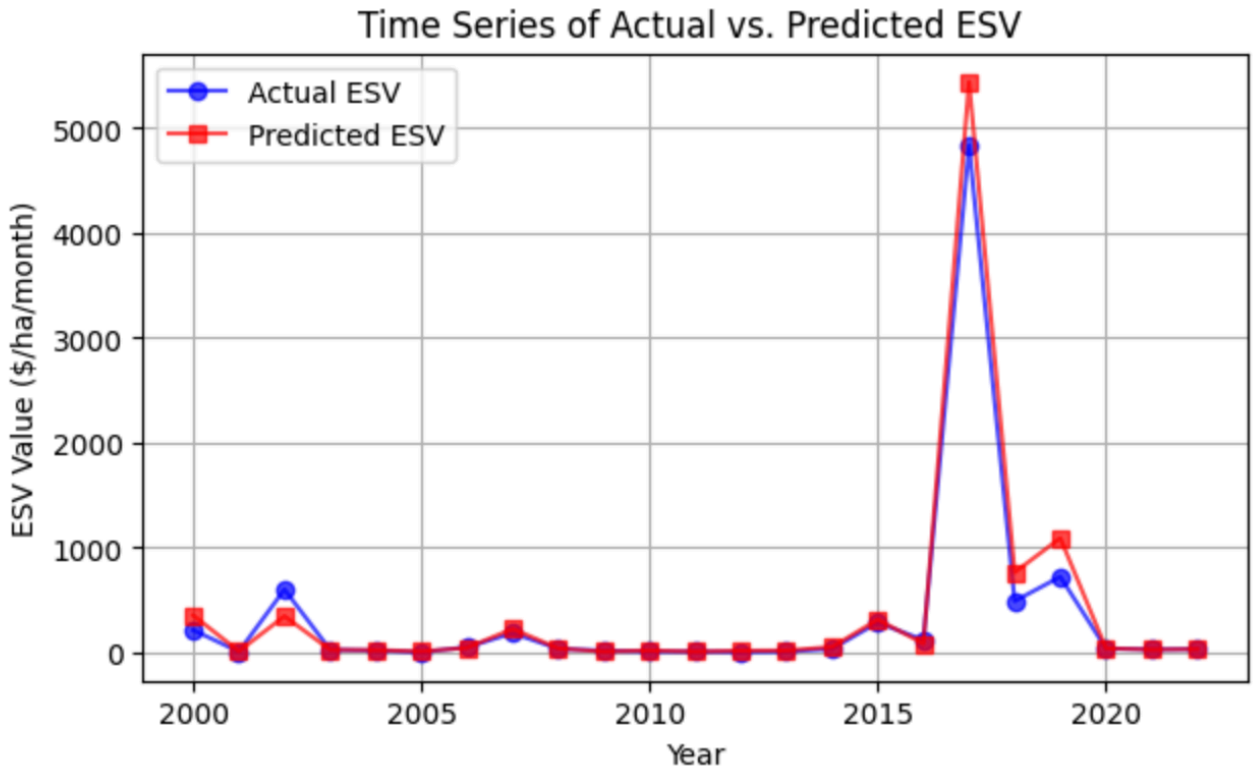
p-value (≈ 0) → We can reject the null hypothesis : the correlations are **highly significant**
p-value >.05 or .01 → **no significant linear relationship**

ESV-kNDVI-Precipitation Correlations (2/2)



Strong Pearson correlations between precipitation and KNDVI in Asia, North and South America and anti-correlation in Oceania but other values remain weak, indicating ESV is influenced by additional factors beyond KNDVI and precipitation for the selected sites.

ESV Prediction with RF



Random Forest predicts ESV series extremely well most of the time (R^2 = 0.99, MAE = 0.64). However, the very large RMSE (11.029) shows that the model occasionally makes **rare but very large errors**. the model struggles with sudden changes (e.g., spikes, seasonality shifts, structural breaks).

Other methods and results are available on Github: https://github.com/LaureBerti/CEST_2025

Discussion & Perspectives

Discussion & Perspectives

Limitations of the analysis

- Certain forest biomes or ecozones were not considered (e.g., cold climate evergreen forest, perennial agroforestry)
- Many valuation methods and data are available in the ESV database and could be analyzed in the same way
- Averaging ESV-Precipitation-kNDVI data across sites per continent and biome may mask actual correlations and hinder the predictive models
- Correlations may not be linear

Perspectives

- Extend the study with more ESV sites, valuation methods and finer-grained biome data
- Study the effect of teleconnections on forest resilience and forest ESV
- Reduce the spatial focus of the analysis to regional scale

Thank You!

Contact Author: Laure Berti-Equille

laure.berti@ird.fr

https://laureberti.github.io/website/
https://github.com/LaureBerti/CEST_2025

IRD UMR ESPACE-DEV
Montpellier, France

https://www.eco2adapt.eu/

cest.gnest.org

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