International Max Planck Research School for Global Biogeochemical Cycles

On the significance of global greening and browning trends

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Introduction

- Many studies have consistently reported on global greening trends
- These trends do not withstand rigorous significance testing - they are not found significant after accounting for multiple testing
- Our results greatly reduce the focal areas of greening that should be investigated in detail with proper trend-attribution methods

Introduction

Motivation

When we compare 3 or more means in an ANOVA, our F statistic determines overall significance, but we perform a post-hoc test (Bonferroni, Scheffe, Tukey, etc.) to determine which pair of means are different. Similarly, when performing a hypothesis test at each grid cell, we can do a post-hoc test to determine which grid cells are significant.

Introduction

- It could be the case that most discoveries are false positives
- In the environmental sciences the focus has been mainly on Bonferroni and related methods
- Our work - Permutation methods! Used successfully in other areas (e.g., neuroimaging, genetics)

Permutation methods

We focus on a permutation method based on clustering (Cortes et al. 2020)

- Motivation: If enough neighboring grid cells are significant, then this is likely to be a true spatial pattern
- How many significant neighbouring grid cells are enough? Determined empirically by the permutation method
- Spatial autocorrelation is taken into account
- Shown to have higher statistical power and better detect spatial patterns when compared to traditional Bonferroni and related methods

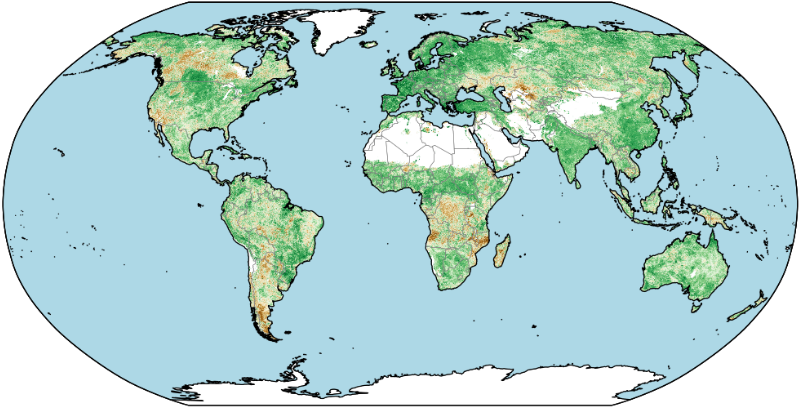
This study

- Mann-Kendall trend test on yearly averages
- Corrected for temporal autocorrelation
- Permutation method based on clustering to account for multiple hypothesis testing
- Significance level of $\alpha = 0.05$
- Five global datasets of Leaf Area Index

Dataset	Domain and resolution
GIMMS 3g	Global, $1/12^\circ$, 15-day, 1981-2018
NOAA CDR	Global, 0.05°, daily, 1981-2019
Land Long Term Data Record	Global, 0.05°, daily, 1981-2018
LTDR MOD15A2	Global, $1/12^\circ$, 8-day, 2001 - 2018
SPOT/PROBA-V	Global, 0.5°, 10-day, 1999 - 2018

Results

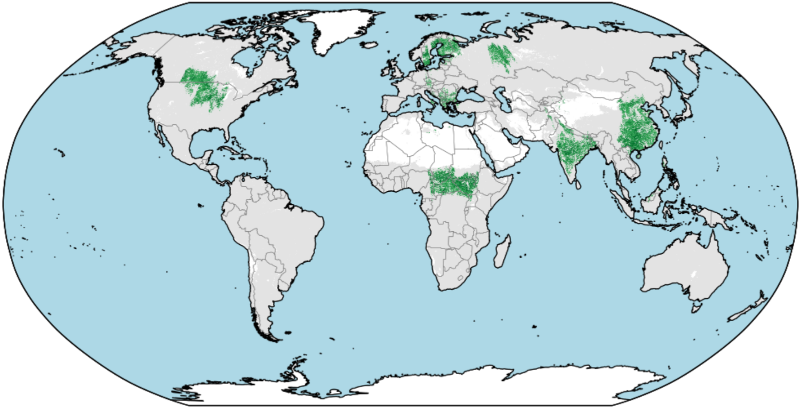
Results of applying the MK test for the LAI data from GIMMS 3g - raw results. Greening and browning trends are shown in green and brown, respectively



Cortés et al. (in preparation)

Results

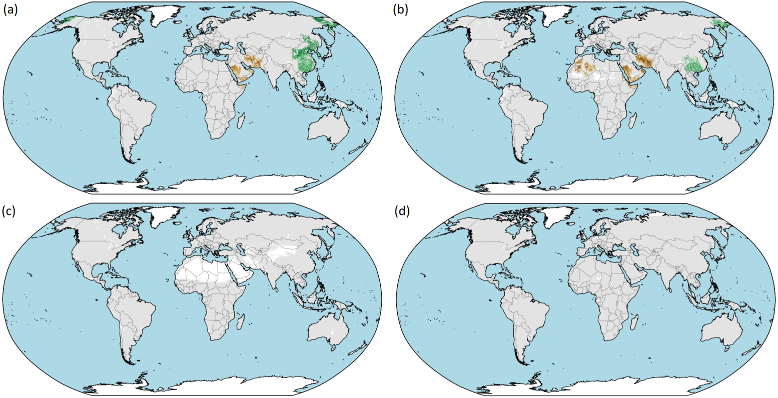
Results of applying the MK test for the LAI data from GIMMS 3g - corrected for multiple testing ($\alpha = 0.05$). Greening and browning trends are shown in green and brown, respectively



Cortés et al. (in preparation)

Results

Results of applying the MK test for the LAI data, corrected for multiple testing ($\alpha = 0.05$), for (a) NOAA CDR, (b) Land Long Term Data Record, (c) LTDR MOD15A2, and (d) SPOT/PROBA-V. Greening and browning trends are shown in green and brown, respectively



Cortés et al. (in preparation)

Results

Contribution of countries to global greening (GIMMS 3g dataset, $\alpha = 0.05$)

Rank	Area of significant greening (million km2)	Proportion of (non-barren) land showing greening (%)
1	China (2.54)	Hong Kong S.A.R. (100)
2	India (1.12)	South Sudan (78.4)
3	USA (.78)	Finland (68.4)
4	South Sudan (.48)	Central African Republic (67.9)
5	Canada (.43)	Macedonia (63.2)
6	Central African Republic (0.42)	Sweden (61.4)
7	Russia (.42)	Bangladesh (54.7)
8	Chad (0.31)	Chad (54.2)
9	Sudan (0.28)	Kosovo (51.8)
10	Sweden (0.26)	Bulgaria (50.5)

Cortés et al. (in preparation)

Results

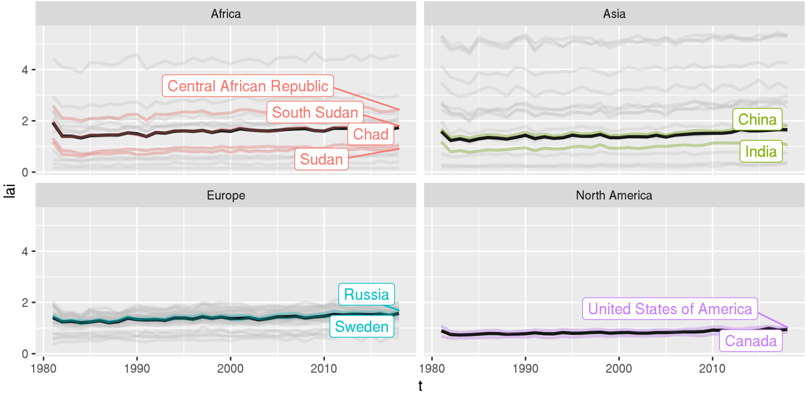
Contribution of continents to global greening (GIMMS 3g dataset, $\alpha = 0.05$)

Rank	**Area of significant greening and contribution to overall global greening (million km^2 - %)**	**Proportion of (non-barren) land showing greening (%)**
1	Asia (3.89 - 46.6%)	Asia (18.4)
2	Africa (1.81 - 21.7%)	Africa (9.2)
3	Europe (1.42 - 17.1%)	North America (7.2)
4	North America (1.21 - 14.5%)	Europe (6.3)

Cortés et al. (in preparation)

Results

Time series of observed LAI (GIMMS 3g dataset, $\alpha = 0.05$). Each line represents a country mean, the black line represents the continent mean. Highlighted countries are the top 10 contributors to global greening in terms of area of significant greening



Cortés et al. (in preparation)

Results

- Datasets with data since 1981 (GIMMS 3g, NOAA CDR, and Land Long Term Data Record) agree on China's greening, and each of them detect greening patterns around the world
- Other datasets (LTDR MOD15A2 and SPOT/PROBA-V) are not able to detect any greening
- Using the GIMMS 3g dataset, we find that Asia (mostly China and India) accounts for most of the significant global greening, both in terms of area and proportion of land showing greening
- Our permutation method is effective at finding spatial patterns around the globe (see also extra slides)

Thank you!

Questions?

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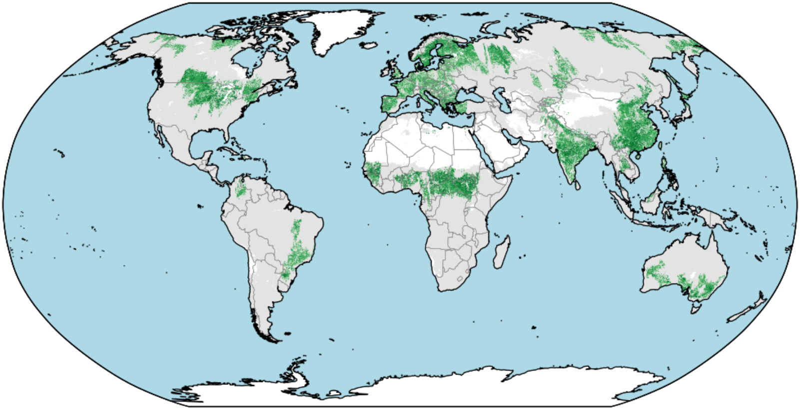
References

Cortés, José & Mahecha, Miguel & Reichstein, Markus & Brenning, Alexander. (in press). Accounting for multiple testing in the analysis of spatio-temporal environmental data. Environmental and Ecological Statistics. 10.1007/s10651-020-00446-4.

More results...

Results of applying the MK test for the LAI data from GIMMS 3g - corrected for multiple testing ($\alpha = 0.10$). Greening and browning trends are shown in green and brown, respectively



Cortés et al. (in preparation)