Adapting Afforestation Patterns Considering Their Local Biogeophysical Induced Cooling and Warming

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1. Motivation

- Land-based options are hoped to play a key role in mitigation efforts.
- Scenario building models currently neglect their BGP impact.

Objective

Reevaluate afforestation as a mitigation option considering BGP effects as an incentive or penalty

2. Tools

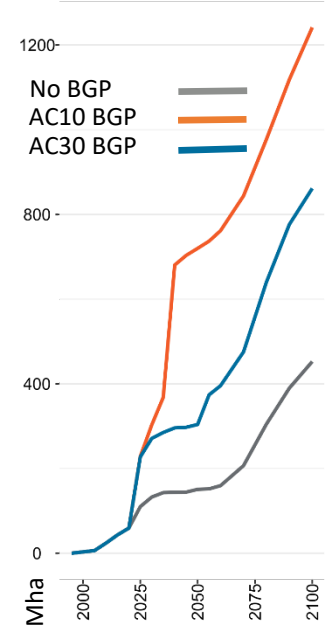
Optimizing global agriculture with the land-use model MAgPIE for a range of possible developments both in climate (RCPs) and society (SSPs).

3. Method

The carbon equivalent of BGP induced temperature changes will be added as incentive/penalty to afforestation driven by the carbon price.

4. Results

- Marked difference in afforestation development and patterns.
- High sensitivity to the onset of BGP effects.



BGP – Biogeophysical
MAgPIE - Model of Agricultural Production and its Impact on the Environment

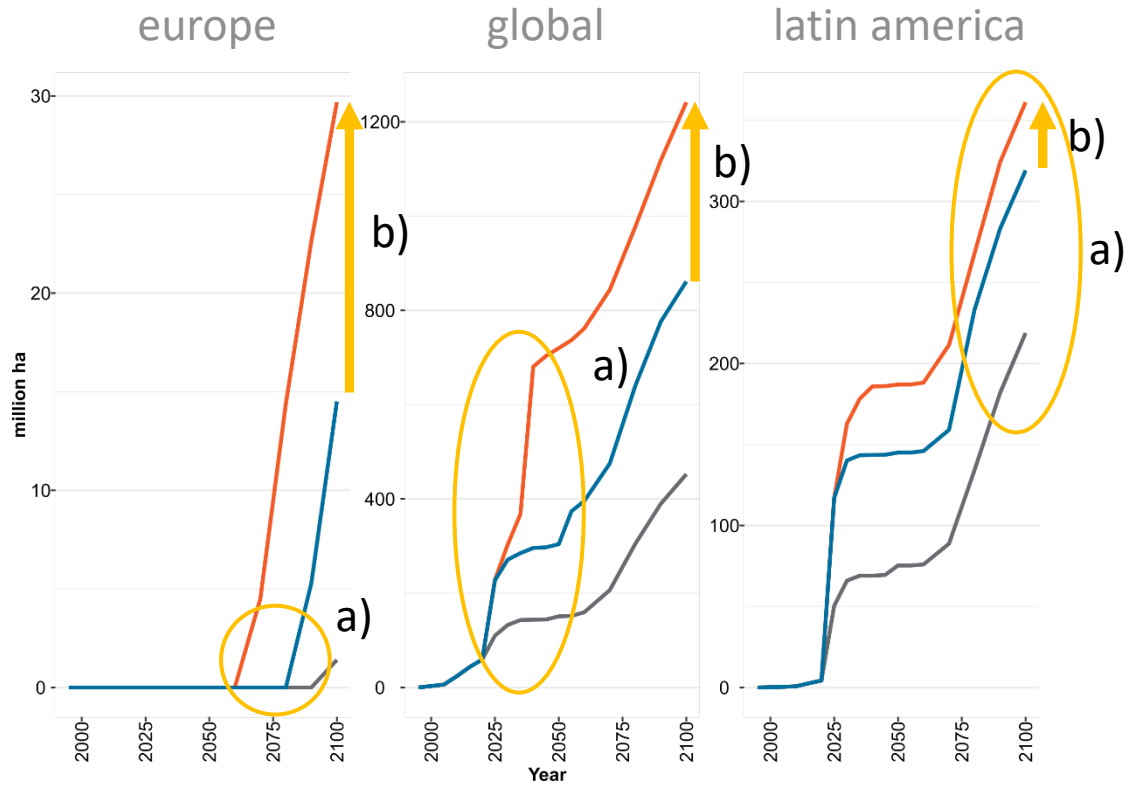
RCP – Representative Concentration Pathways
SSP – Shared Socioeconomic Pathways

Results 1/2 Afforestation Area

No BGP

AC10 BGP

AC30 BGP



Million ha of afforestation in Europe, the Globe, and Latin America until the end of the century. (Grey) Baseline case without BGP implementation; (orange) BGP impact in effect after 10 years of new plantation; (blue) BGP impact in effect after 30 years of new plantation.

1. Findings

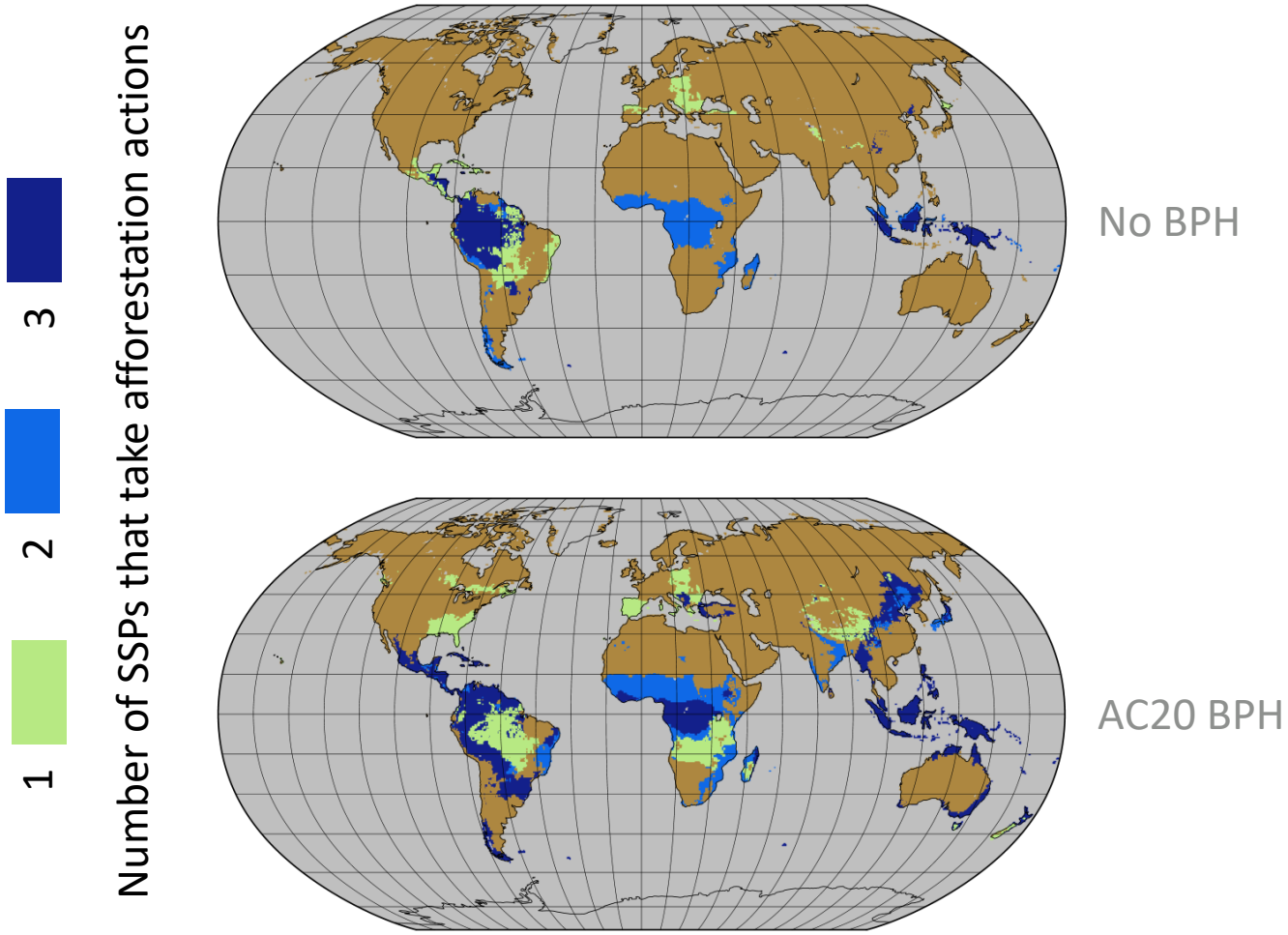
a) Endogenous BGP consideration influences the onset, slope, and resulting afforestation area.
b) Resulting afforestation area is sensitive to the timing of BGP effects.

2. Setup

- SSP1
- Unrestricted afforestation
- Annual BGP impact estimates from observation-based studies[1,2].

1, Bright et al. 2017
2, Duveiller et al. 2018

Results 2/2 Afforestation Patterns



Global afforestation action frequency over SSP 1,2, and 5 at the end of the century. (Top) baseline runs without BGP implementation, (bottom) BGP impact felt 20 years after new plantation is established. Count of scenarios (SSPs) that use afforestation as a mitigation option in any grid-cell is indicated by the coloring.

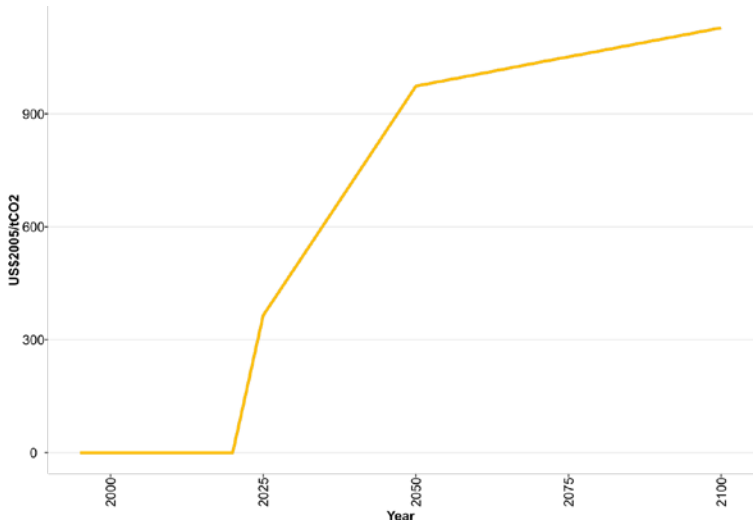
1. Findings

a) Increase in total area pushes afforestation mostly in the tropics.
b) Afforestation becomes more robustly viable over SSPs in central Africa/America, and China.

2. Outlook

- Model runs with higher resolution
- More scenarios (SSPs) and carbon price pathways.
- Assessment of the BGP induced change in absolute CO2 removal.

Method 1/2 BGP as a Cost Incentive / Penalty



Carbon price

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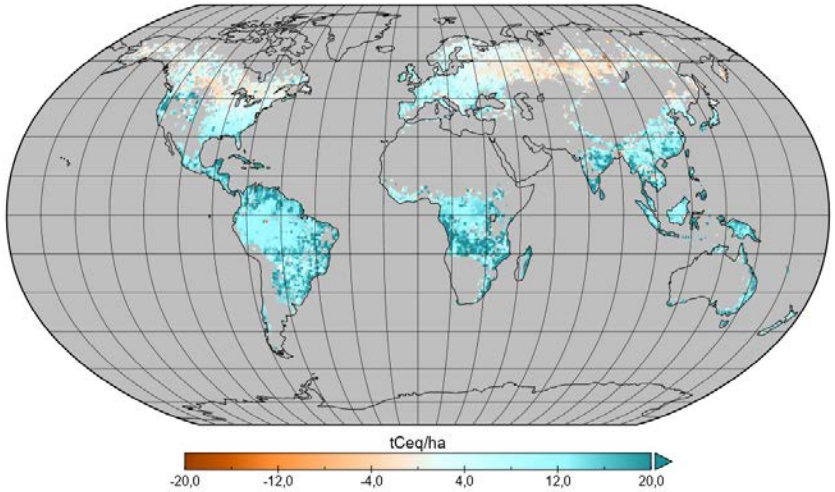


BGP carbon equivalent

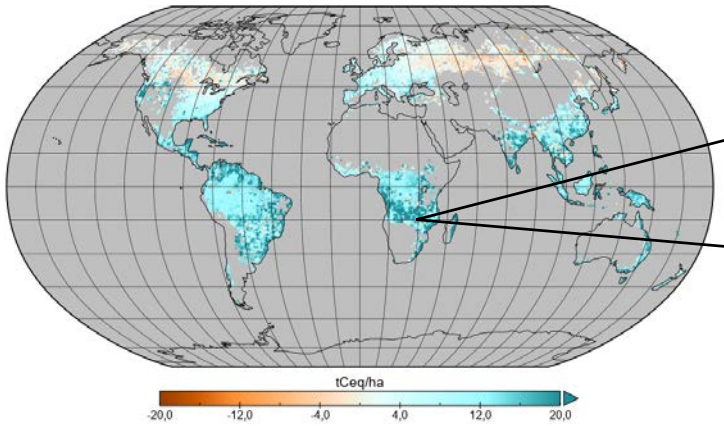
= **$ BGP incentive / penalty**

Incentive / Penalty

The cost incentive or penalty of the BGP effects of afforestation is derived by multiplying the carbon price by the carbon equivalent of BGP induced temperature changes (see next slide). This allows the model (MAgPIE) to endogenously adapt afforestation decisions informed by BGP effects.

Method 2/2 Carbon Equivalent of BGP Effects

$$C_{eq}^{BGP}(i,j) = \frac{\Delta°C^{BGP}(i,j)}{\mathrm{TCRE}(i,j)} \times \frac{1}{A_{SFC}}$$



Example of one grid-cell

$$\frac{10tCeq}{ha} = \frac{-1°C}{\frac{+2.5°C}{1218GtC}}^{1,2,3} \times \frac{1}{510 \times 10^8\ ha}$$

The Carbon Equivalent Metric

We compute the carbon emission equivalent (C_{eq}^{BGP}) that would theoretically produce the same temperature response as the temperature change induced by local BGP effects[1,2] ($\Delta°C^{BGP}(i,j)$). We obtain the local contribution by dividing by the global surface area (A_{SFC}). The local climate sensitivity to carbon emissions ($\mathrm{TCRE}(i,j)$) is derived by the CMIP5 +1% annual CO2 increase experiments[3].

1, Bright, R. M. *et al.* Local temperature response to land cover and management change driven by non-radiative processes. *Nat. Clim. Change* (2017). doi:10.1038/nclimate3250

2, Duveiller, G., Hooker, J. & Cescatti, A. The mark of vegetation change on Earth's surface energy balance. *Nat. Commun.* **9**, 679 (2018)

3, Taylor, K.E., R.J. Stouffer, G.A. Meehl: An Overview of CMIP5 and the experiment design." Bull. Amer. Meteor. Soc., 93, 485-498, doi:10.1175/BAMS-D-11-00094.1, 2012