Accounting for Local Temperature Effect Substantially Alters Afforestation Patterns

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1 Introduction

Almost all scenario building models completely neglect the cooling and warming induced by biogeophysical (BGP) effects of re- and afforestation. Our work introduces the first endogenous implementation of BGP effects into a scenario building model (MAgPIE[1]). This allows us to reevaluate and adapt re- and afforestation patterns in mitigation scenarios considering their local BGP effects.
We compute the carbon equivalent of the BGP induced local temperature change which can then be driven by the carbon prize to add the appropriate cost incentive or penalty of local BGP effects.
We show that despite the penalty to boreal re- and afforestation, considering local BGP effects increases climate mitigation motivated re- and afforestation.

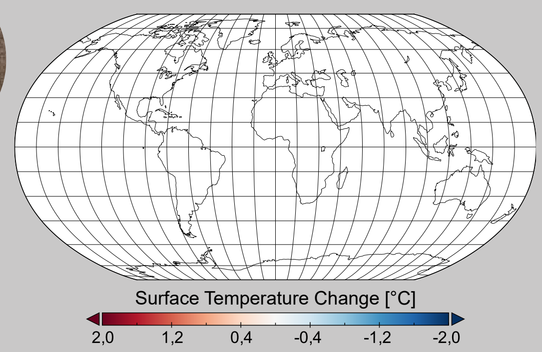


Fig 1. Input data: Local annual temperature change due to the BGP response to afforestation. Based on the observation based (both remote sensing and on-site) studies of Bright et al. 2017[2] and Duveiller et al. 2018[3]

2 Results

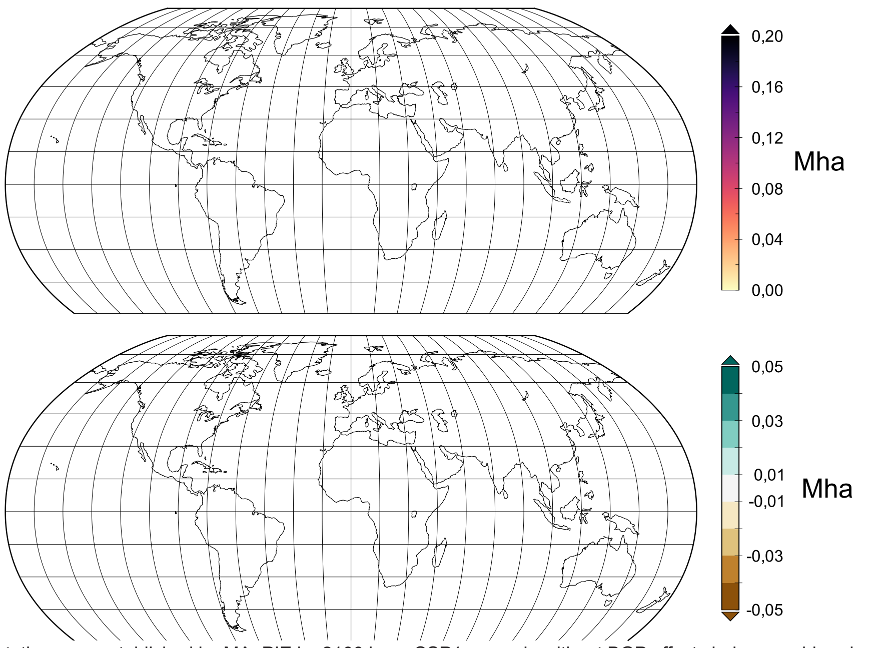


Fig 2. (Top) Afforestation area established by MAgPIE by 2100 in an SSP1 scenario without BGP effects being considered. (Bottom) Difference between the afforestation area in the same SSP1 scenario under the same carbon price but with the endogenous consideration of local BGP effects of afforestation and the control run (top) with no BGP effects being considered. Additional/less afforestation area in the scenario that considers BGP effects are marked in green/brown.

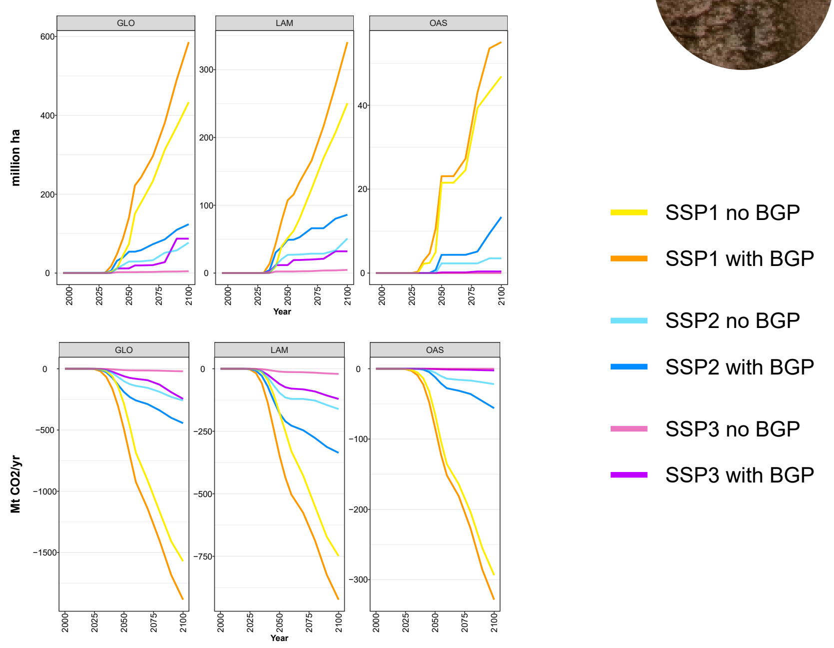
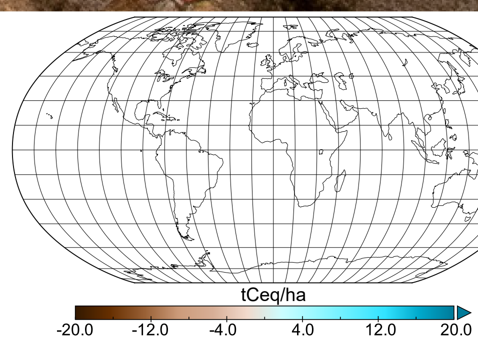


Fig 3. (Top row) Accumulated afforestation area in Mha and (bottom row) yearly negative emissions induced by afforestation established by MAgPIE over three SSPs each with and without endogenous consideration of local BGP effects. From left to right for the whole globe, Latin America, and Southeast Asia.

4 Conclusion

- The endogenous consideration of the local BGP induced temperature response of afforestation increases tropical afforestation viability at the same carbon price.This increase in afforestation area in the tropics ultimately leads to more carbon being removed at the same driving price.
- Regions can become less viable to afforestation even though the local BGP effect increases the incentive if they experience fewer benefits from BGP effects relative to other regions. This further enhances the focus on tropical- compared to higher latitude afforestation.

3 Data and Method



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

-We compute the carbon emission equivalent (Ceq) that would theoretically produce the same temperature response as the temperature change induced by local BGP effects (Fig 1./d°C). We obtain the local contribution by dividing by the global surface area (𝐴sfc). The local climate sensitivity to carbon emissions (TCRE) is derived by the CMIP5 +1% annual CO2 increase experiments.
-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. This allows the model (MAgPIE) to endogenously adapt afforestation decisions informed by BGP effects.

5 References

1. Jan Philipp Dietrich, Benjamin Leon Bodirsky, Florian Humpenöder, et al. MAgPIE 4-a modular open-source framework for modeling global land systems. Geoscientific Model Development, (2019), 1299-1317, 12(4). doi: 10.5194/gmd-12-1299-2019.
2. Ryan M. Bright, Edouard Davin, Thomas O'Halloran. Local temperature response to land cover and management change driven by non-radiative processes. Nature Climate Change, 7(4):296–302, 4 2017. doi: 10.1038/nclimate3250.
3. Gregory Duveiller, Josh Hooker, and Alessandro Cescatti. A dataset mapping the potential biophysical effects of vegetation cover change. Scientific Data, 5:180014, 2 2018. ISSN 2052-4463. doi: 10.1038/sdata.2018.14