EGU22-10157, updated on 02 Dec 2022
https://doi.org/10.5194/egusphere-egu22-10157
EGU General Assembly 2022

How land cover changes affect ecosystem productivity

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Historically, many forests worldwide were cut down and replaced by agriculture. While this substantially reduced terrestrial carbon storage, the impacts of land-use change on ecosystem productivity have not been adequately resolved yet.

Here, we apply the machine learning algorithm Random Forests to predict the potential gross primary productivity (GPP) of forests, grasslands, and croplands around the globe using high-resolution datasets of satellite-derived GPP, land cover, and 20 environmental predictor variables.

With a mean potential GPP of around 2.0 kg C m^{-2} yr^{-1} forests are the most productive land cover on two thirds of the global suitable area, while grasslands and croplands are on average 23 and 9% less productive, respectively. These findings are robust against alternative input datasets and algorithms, even though results are somewhat sensitive to the underlying land cover map.

Combining our potential GPP maps with a land-use reconstruction from the Land-Use Harmonization project (LUH2) we estimate that historical agricultural expansion reduced global GPP by around 6.3 Gt C yr^{-1} (4.4%). This reduction in GPP induced by land cover changes is amplified in some future scenarios as a result of ongoing deforestation but partly reversed in other scenarios due to agricultural abandonment.

Finally, we compare our potential GPP maps to simulations from eight CMIP6 Earth System Models with an explicit representation of land management. While the mean GPP values of the ESM ensemble show reasonable agreement with our estimates, individual Earth System Models simulate large deviations both in terms of mean GPP values of different land cover types as well as in their spatial variations. Reducing these model biases would lead to more reliable simulations concerning the potential of land-based mitigation policies.