CO_2FORKlim

Project summary

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During their growth period, forests actively remove large amounts of CO_2 from the atmosphere and store the carbon long-term in their biomass (Luyssaert, et al., 2010). In this way, greenhouse gas concentrations in the atmosphere are reduced and more long-wave radiation can leave the Earth system, resulting in a cooling of Earth's climate. Afforestation is therefore generally considered as an important mitigation strategy to achieve the goals of the Paris Climate Agreement, keeping the average global near-surface temperatures below 2°C compared to pre-industrial levels (Harper et al., 2018; Roe et al., 2019).

Besides this beneficial effect on the global climate system, afforestation additionally changes the biogeophysical characteristics of the land surface (Pielke et al., 2011). In general, a forest is darker than other vegetation types with the consequence that it absorbs more short-wave solar radiation (Bonan, 2008). Moreover, due to its high surface roughness and its high transpiration potential, a forest is able to transform the absorbed solar radiation very effectively into turbulent heat and release the energy into the atmosphere (Breil et al., 2020). As a result, the vegetation surface remains comparatively cool despite an increased amount of absorbed solar radiation (Lee et al., 2011). According to the Stefan-Boltzmann law, cooler surfaces emit less long-wave radiation, by which in turn more energy remains in the Earth system.

Recent studies show that through this process, afforestation in Europe leads to an overall reduction in outgoing long-wave radiation (Breil et al., 2023). That means that although CO_2 concentrations are reduced with afforestation, and a thus more long-wave radiation should be able to pass the atmosphere, in total less energy is leaving the Earth system. Since the absorption of short-wave solar radiation is simultaneously increased, afforestation has an overall warming effect on the European climate (Breil et al., 2023). However, this effect of afforestation is generally not taken into account in the development of climate mitigation strategies. The suitability of forests as mitigation strategy is only assessed by their capability to remove CO_2 from the atmosphere. Socio-economic strategies developed to meet the targets of the Paris Climate Agreement therefore envisage afforestation over large parts of Europe (Hoffmann et al., 2022). Thus, in these strategies it is tried to limit the global warming with a measure that leads to a regional warming in Europe, which is obviously counter-productive. The potential to reach the 2°C target is consequently spuriously estimated, why afforestation as a mitigation strategy in Europe has to be rethought.

In the framework of this project (funded by the Vector Stiftung), therefore, we intend to develop new afforestation strategies for Europe in which, on the one hand, the positive effects of CO_2 removal are preserved and, on the other hand, negative effects of the changed surface properties are compensated. Thus, we are searching for tree species with a high CO_2 absorption rate, bright leaves, and a best possible balance between transformed radiative energy into turbulent heat and emitted long-wave radiation. For this purpose, in a first step, an inventory of tree species suitable for planting in the respective regions of Europe was conducted. On the basis of this inventory, now idealized high-resolution global climate simulations will be performed with the fully coupled Earth System Model ICON-ESM (Jungclaus et al., 2022), whereby in each simulation Europe will be completely afforested with one of the identified tree species. By analyzing the results of these idealized afforestation experiments, the tree species with the best energy balance in the respective regions of Europe will be identified. Subsequently, a new ICON-ESM simulation will be performed, in which in every region of Europe only the tree species with the best energy balance will planted. By comparing the results of this experiment with the results of a reference simulation, in which the real land cover is used, it will be possible to identify all the regions in Europe where afforestation really has a climate benefit. Finally, a last ICON-ESM simulation will be conducted, in which only the regions of Europe with a climate benefit of forests are afforested and compared again with the reference simulation. In this way, the maximum potential climate benefit of afforestation in Europe will be quantified. This will constitute important information for decision makers to design and implement appropriate climate mitigation strategies, helping to achieve the goals of the Paris Climate Agreement.

However, this kind of fully coupled Earth System Model simulations with ICON-ESM are computationally very expensive. Therefore, the highly resolved global climate simulations need to be performed on a supercomputer, like LEVANTE.

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