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# Conceptualizing green water within the planetary boundary for freshwater use

Given that the current state of the Earth is the only state that we know for certain that humanity can thrive in, it is a moral imperative to maintain a sound and stable functioning Earth system for future generations. By identifying and quantifying nine distinct but partly overlapping environmental tension zones of human interference, the Planetary Boundary framework is aiming at setting the frame of Earths natural limits for sustainable development, the safe operating space.

The increasing demand for land and water resources to sustain agricultural production exerts an unprecedented pressure on terrestrial surfaces. This emerging pressure includes processes such as transforming the land surfaces structure and vegetation, redirecting river discharge to irrigate crops, applying artificial fertilizers and fragmenting concatenated landscapes into agricultural parcels. This, of course, has far-reaching implications for the interfering physical, biological and chemical processes, cycles and spheres of the Earth system.

One of the aspects experiencing vast human pressure due to land-use change is the water cycle. The global water cycle has been identified as one of the nine environmental tension zones within the planetary boundary framework, the so-called Planetary Boundary for Freshwater use. An over-usage of the water cycle, is estimated to have detrimental effects on the functioning of our planet and thereby on humankind itself. Nevertheless, the current definition of the planetary water boundary is solely based on blue water, that is river streamflow, while leaving green water, that is the water flux from terrestrial surfaces to the atmosphere, out. This causes a shift of attention towards the blue fraction of the water cycle while leaving green water, which is an even bigger fraction of the water cycle nearly unattended. Green water plays a vital role for the survival and development of the terrestrial biosphere, carbon sequestration by vegetation and moisture transport from the surface to the atmosphere.

This study employed a *dynamic global vegetation model* (a computer model allowing for simulating soil, water and vegetation and their underlying processes for both, natural vegetation and human land-use on a global scale) to quantify the human-induced changes in the water cycle. It was possible to show that human activity alters the total amount and composition of green water. The results reveal a strong spatially heterogeneous bias which is the result of underlying processes. Deforestation, on the one hand, accounts for a significant decrease of green water

flow and a shift towards a pathway which is not plant-meditated. This trend is partly balanced out by redirected runoff in the form of irrigation, causing an increased water flux. The thesis succeeded in demonstrating that humanity is a main agent of change of green water on the planetary scale. Additional advice is given in the form of a qualitative and quantitative fundament for implementing green water into the Planetary Boundary framework. A step which is crucial to undertake in order to have a more holistic representation of human interferences with the water cycle in the Planetary boundary framework.

**Keywords:** Physical Geography · Ecosystem Analysis · Green water · Planetary boundary · Water stress · Land-use · Moisture recycling · Land use modelling · Evapotranspiration · Earth system · Potential natural vegetation

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