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How forests transpiration and interception evaporation can buffer variations in precipitation downwind

Stefan C. Dekker[1], John C. O'connor[1], Arie Staal[1], Obbe A. Tuinenburg[1], Karin T. Rebel[1], and Maria J. Santos[2]
[1]Utrecht University, Copernicus Institute of Sustainable Development, Utrecht, Netherlands (s.c.dekker@uu.nl)
[2]Department of Geography, University of Zürich, Zurich, Switzerland

Forests are important to regulate water-climate relationships, providing important ecosystem services locally and elsewhere. Therefore, understanding forest hydrology is crucial to understand the flows of these ecosystem services, and attribute the origins to either transpiration and interception as these can have very different underlying mechanisms. Atmospheric moisture recycling effectively increases the amount of usable water over land as the water can undergo multiple precipitation–evapotranspiration cycles. Forest contribution to atmospheric moisture recycling can come from water pressure deficit driven water transpiration through the stomata, or via evaporation of surface water intercepted in the canopy during precipitation. Disentangling these two pathways is fundamental as the former is dependent on the ability of the deep roots of trees to access groundwater facilitating a constant transpiration flux throughout the dry season, while the latter is fundamentally dependent on precipitation and canopy architecture and leaf morphology. We have demonstrated that forests can buffer precipitation variability elsewhere, for tropical and other types of forests. However, it is not known whether this buffering effect occurs directly through forest transpiration or whether indirect forest interception evaporation has a buffering effect as well. Here we apply a state-of-the-art Lagrangian moisture tracking model (UTrack) to study globally whether forests in the upwind precipitationshed can lead to a reduction in monthly precipitation variability downwind. Indeed, we found that forests are fundamental to reduce precipitation variability downwind in 10 out of 14 global terrestrial biomes, specifically for all forest biomes except Mediterranean forests. On average, if 50% of precipitation originates from forest, there is a strong buffering effect with an average reduction of 60% in the coefficient of variation of monthly precipitation. We also observed that a high fraction of precipitation from non-forest land sources has the opposite effect, that is, no buffering effect. The average variation of monthly precipitation was 69% higher in areas where 50% of precipitation originates from non-forest land sources in the precipitationshed. We also observed that the role of forest interception evaporation is less important than the role of forest transpiration for buffering precipitation variability. The largest buffering effect was found for the tropical forest biomes, mainly Amazon and Congo, while moisture recycling over Southeast Asia was mostly contributed by the surrounding ocean. For temperate biomes, the buffering capacity of forests is lower, related to shallower rooting depths and that large proportions of temperate forests are in areas dominated by precipitation from non-forested land or ocean, such as western Europe. Nevertheless, there is

still a significant role in buffering precipitation and potentially this buffering capacity can be increased with large scale reforestation projects to mitigate climate change. Our findings clearly support an important role of forests in buffering precipitation downwind. Forests hereby regulate the climate system, which can become unbalanced if this regulating ecosystem service is removed. Furthermore, the importance of this mechanism is also relevant to maintain other processes, such as food production and highlights the tight connections between forests and other processes and ecosystem services