Effects of large scale tree plantations on local climate: What potential for rubber tree plantations?

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Extended abstract

Large-scale land cover changes are occurring throughout tropical areas in order to respond to the increasing global demand in plant materials such as wood, oil, textiles, food products and natural rubber. In particular, the area of tropical tree plantations have strongly increased over the last decades, reaching about 20 million hectares for fast growing eucalypt plantations (Booth, 2013), or 14.3 million hectares for rubber tree plantations (IRSG 2018), most of them established in Southeast Asia. Such land use changes (LUC) have the potential to impact the local, regional and global climates due to modifications of the albedo (which affects the surface radiative budget), of surface roughness, and canopy stomatal and aerodynamic conductance (which affect the partitioning of available energy between latent and sensible heat fluxes), and of the carbon sources and sinks strengths (which affect the atmospheric CO_2 concentrations).

It is well known that the replacement of natural forests by tree plantations leads to large losses of biodiversity and release of CO_2 to the atmosphere. In contrast, afforestation of croplands, grasslands and degraded shrublands generally results in increases in landscape carbon stocks, thus contributing to climate change mitigation. Furthermore, tree plantations can contribute to the reduction of fossil carbon emissions, when the wood from the plantations is used as a substitute of fossil combustible, e.g. by replacing the coke by charcoal in the steel industry (Fallot et al. 2009) or in power plants (Waewsak et al. 2020). Similarly, using natural rubber (renewable product) as a substitute to synthetic rubber (produced from fossil carbon) avoids fossil carbon dioxide emissions.

In addition to the global warming attenuation through carbon sequestration and avoidance of fossil carbon dioxide emissions, tree plantations can mitigate warming through evaporative cooling (Peng et al. 2014). This is due to their high actual evapotranspiration (AET) in comparison to other land uses such as crops or grasslands. Although in boreal areas the evaporative cooling of tree plantations can be over-compensated by a warming resulting from low albedo, in tropical areas the cooling by AET generally largely dominates the warming effect of low albedo, thus resulting in a net cooling effect of tree plantations and natural forests (Bonan 2008, 2016; Prevedello 2019). In this presentation we report data obtained in fast-growing

eucalypt plantations in south-eastern Brazil, and in rubber tree plantations in Thailand, and results from previous published studies that confirm the cooling trends of these tropical tree plantations.

In Brazil, the mean AET measured by eddy covariance over a seven-year eucalypt rotation (~1400 mm yr^{-1}) represented about 90% of the annual rainfall, and the latent heat flux associated to this high AET represented about 88% of the available energy (net radiation), thus suggesting a high evaporative cooling. Furthermore, comparison of land surface temperatures (LST) derived from satellite images showed lower LST over this plantation and over nearby eucalypt and pine plantations than over grasslands, and soybean and sugar cane plantations, which is consistent with results reported in some previous studies (e.g. Jackson et al. 2008). Among other factors, the high AET of these south-eastern eucalypt plantations was allowed by a good fertilization regime, which increases both tree growth and water use (Christina et al. 2018) and by the ability of eucalypt trees to rapidly develop a deep root system (>10 m deep two years after planting; Pinheiro et al. 2016; Germon et al. 2019) allowing them to get access to large amounts of soil water (Christina et al. 2017).

In rubber tree plantations in Thailand we found AET of about 1150 mm yr^{-1}, which falls in the lower range of values reported previously for rubber tree plantations in north-eastern Thailand and Cambodia (1210 and 1450 mm yr^{-1}; Giambelluca et al. 2016), and south-western China (Tan et al. 2011). As for eucalypt plantations, the high AET values measured in some rubber tree plantations growing on deep soils could partly result from deep rooting (Pierret et al. 2016; Giambelluca et al. 2016). The mean proportion of net radiation used for evapotranspiration in the rubber plantations (0.73) was similar to that reported by Giambelluca et al. (2016) (0.72). These high values are similar to that reported for tropical rainforests (0.72; Fisher et al. 2009), thus suggesting that well-managed rubber tree plantations might behave similarly to tropical rainforests in term of evaporative cooling and moisture recycling to the atmosphere (Staal et al. 2018; Zemp et al. 2014).

Further studies are required to better assess the biogeochemical and biophysical effects of rubber tree plantations on the local and regional climate, using field measurements, ecophysiological process-based models, and regional atmospheric models. Evaporative cooling, in particular, may contribute to both local warming mitigation (Ellison et al. 2017) and tree adaptation to increased air temperatures, by keeping leaves to physiologically safe temperatures, thus avoiding overheating and thermal damage. Evaporative cooling, however, is only possible when sufficient soil water is available, and might therefore not operate in marginal areas with low precipitation. Research is also needed to better assess the effects of sylvicultural practices on the feedbacks between rubber tree plantations and local climate.

Keywords: albedo, evaporating cooling, evapotranspiration, carbon, water and energy cycles, biogeochemical and biophysical effects, climate change mitigation and adaptation, rubber tree plantations, eucalypt plantations

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