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Alterations in 'water yield' associated with land use changes under different precipitation regime

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Changes in rainfall regimes and land cover results in complex alterations in plant water use and in ecosystem water balance, which are not well quantified. This results in poor estimates of the 'water yield' (WY; the difference between precipitation, P, input and evapotranspiration, ET, losses), which provides the water available for runoff and re-charge, and ultimately also for human consumption. The objective of this study was to examine the interactions between the effects of land use change (from sparse shrubland to pine forest) on ecosystem WY, and changes in the precipitation regime (from humid Mediterranean to semi-arid conditions). We hypothesized that the forestation increased ET and reduced WY, but this impact diminishes with decreasing precipitation.
We used a new approach centered on a custom-built mobile laboratory of eddy co-variance measurements deployed on a campaign basis (about two weeks per site repeated along the seasonal cycle), that allowed us to measure ecosystem-scale ET together with carbon and energy fluxes and meteorological parameters. Measurements were carried out between the years of 2012-2015 in three paired sites of Pinus halepensis forests and adjacent non-forest ecosystems along the rainfall gradient in Israel, from 755 to 290 mm in annual precipitation. Annual ET was estimated from the campaigns results based on multiple regression analyses with meteorological parameters (relative humidity, RH, temperature, T, and global radiation, Rg) from local meteorological stations that provided continuous data records.
The results indicated that decrease in annual precipitation by a factor of $\sim$2.5, resulted in decrease in ET by a factor of 2.4 from 685 mm, with WY=210 mm, in the humid forest, to 290 mm, with WY= 0 mm, in the dry forest. In the non-forest ecosystems ET showed relatively small decrease (by a factor of 1.3) from 285 mm, with WY=460 mm, to 220 mm, with WY=95 mm. The differences 'Forest-shrubland' in ET decreased from 400 mm to 70 mm between the wet and dry conditions, and in WY decreased from 250 mm to only 95 mm.
We conclude that afforestation is always associated with loss in WY due to increased ET, but the afforestation impact on WY yield is non-linear and diminishes with decreased precipitation. These results provide an incentive to maintain or increase forestry in dry, or drying, conditions to benefit from ecosystem services other than WY (e.g. carbon sequestration, wood production, surface cooling, recreation). Our experimental approach based on the Mobile-Lab provides an alternative to complex manipulation experiments and allow quantification of the effects of land use changes during environmental changes, such as associated with global warming.