Effects of reforestation on the partitioning of precipitation into evapotranspiration, overland flow and recharge in eastern Madagascar

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Introduction

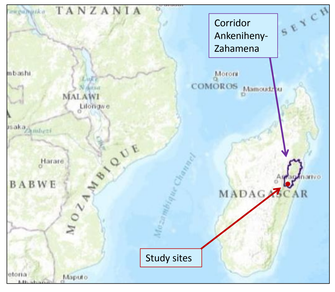
Reforestation is promoted for a wide range of benefits, including carbon sequestration, biodiversity, rehabilitation of degraded land and streamflow regulation. However, surprisingly little is known about how reforestation of degraded land impacts water resources. Transpiration and interception losses likely increase after reforestation. Overland flow may decrease and recharge may increase because the hydraulic conductivity of the soil will likely increase with time since reforestation due to the increase in soil organic carbon and the re-establishment of roots and soil biodiversity. The net result on soil and groundwater recharge and water yield of these two opposing effects is poorly documented, but likely site specific. We, therefore, set out to study how land use and reforestation affect the partitioning of precipitation in evapotranspiration, surface runoff, soil and groundwater recharge and streamflow in eastern Madagascar.

Study site and methods

We study the effects of land use on water resources in the Andasibe area in the Corridor Ankeniheny-Zahamena (CAZ) in eastern Madagascar as part of the P4GES project (Can Paying 4 Global Ecosystem Services values reduce poverty?). The average annual precipitation in the area is 1925 mm/year. The soils are classified as Ultisols and Oxisols.

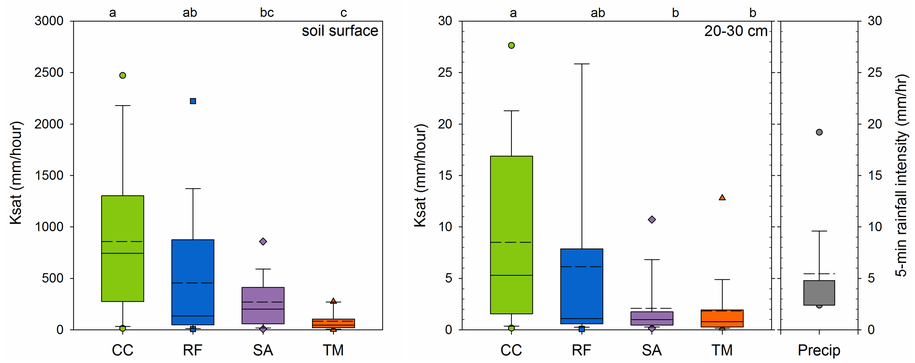
We measured surface and near-surface infiltration rates at five points along a transect in *(i)* closed canopy forest (CC; n=5), *(ii)* recently reforested sites (6-8 years old) (RF; n=4), *(iii)* 3-14 year-old natural regrowth on fallow land (savoka; SA; n=9), and *(iv)* exhausted and severely degraded land (tany maty; TM; n=5).

We, furthermore, installed three research plots (closed canopy forest, reforested tree fallow, and degraded land) to allow quantification of rainfall interception (66 throughfall gauges, 3 throughfall gutters and 5 (RF) or 10 (CC) stemflow gauges per forest site), transpiration (12-21 TDP sapflow sensors per forest site) and surface runoff (2-3, 3 by 10 m runoff plots per site). Each research plot also has a weather station. All collection drums and gauges are emptied daily.



Soil hydraulic conductivity

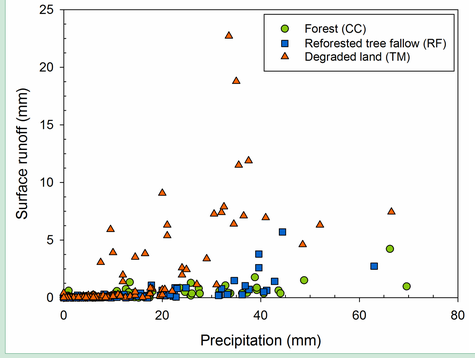
The hydraulic conductivity of the soil decreased rapidly with depth, so that at 30 cm below the soil surface it was lower than common rainfall intensities during the 2014-2015 study period, especially for the reforestation, fallow and degraded sites. The hydraulic conductivity at the soil surface was significantly higher for the forest and reforested sites than for the degraded sites, suggesting that reforestation may reduce the occurrence of infiltration excess overland flow. However, the hydraulic conductivity of the reforested sites was not higher than that of the naturally regenerated fallow sites. It thus remains unclear whether active replanting decreases the time required for restoration of the soil hydrological functioning of degraded land or not.

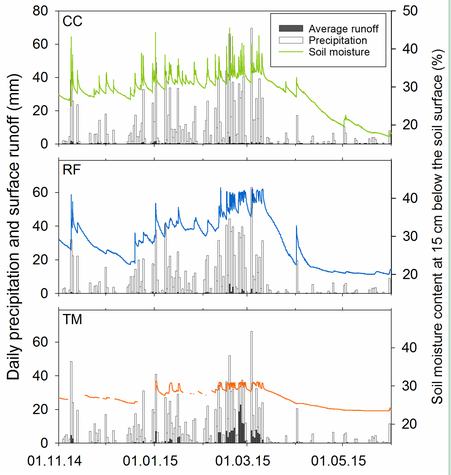


Different letters above the graph denote statistically significant differences between the land uses based on the Kruskal–Wallis one-way analysis of variance

Surface runoff measurements

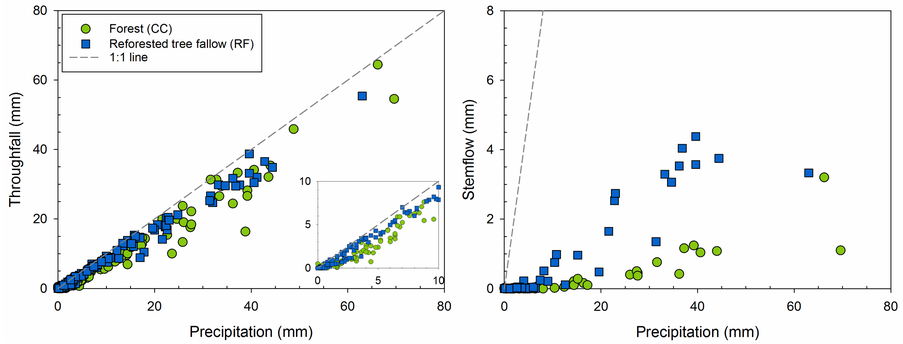
Initial results from the runoff plots suggest that there is indeed more surface runoff in the degraded area than in the reforested fallow or closed canopy forest, particularly during large events at the end of the wet season.

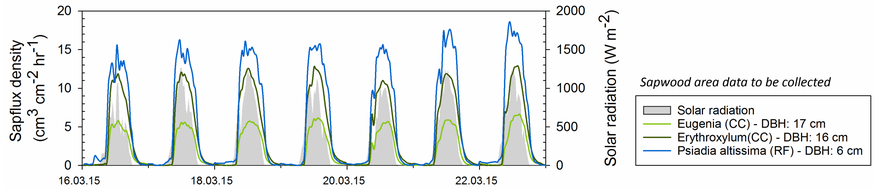




Throughfall, stemflow and transpiration

Interception losses were higher for the forest (25% of precipitation) than for the reforested tree fallow (12%).





Summary (Nov 2014-May 2015 rain season)

While surface runoff is lower in the reforested fallow and forest than the degraded plot, interception losses are higher and transpiration losses are likely higher as well. Therefore, we can not yet determine the net effect of reforestation on soil and groundwater recharge or streamflow.

In addition to these plot scale measurements, we are also measuring streamflow in a 32 ha fallow catchment. We plan to continue the measurements at the plots and the catchment till at least December 2015.

Experimental Plot	Gross rainfall (mm)	Overland flow (mm)	Throughfall (mm)	Stemflow (mm)	Interception loss (mm)
CC	1427	28 (2%)	1045 (73%)	27 (2%)	355 (25%)
RF	1305	31 (2.3%)	1057 (81%)	91 (7%)	157 (12%)
TM	1352	192 (14.2%)	-	-	-

Values in parentheses reflect percentage of precipitation

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