Measurement and modelling of rainfall interception by tropical secondary forests in upland Eastern Madagascar

Introduction

Secondary forests are expanding rapidly and are now the dominant land cover in many tropical regions. However, knowledge of many aspects of the hydrological functioning of tropical secondary forests is severely limited. In particular, little is known about the water use (evapotranspiration) of these often vigorously regenerating forests. As part of a larger venture investigating the various environmental services of different types of land use and land cover in eastern Madagascar, this poster reports rainfall interception losses from a semi-mature and a young secondary forest in the lower montane rain forest belt of eastern Madagascar. For the first time, a physically-based interception model was tested in a tropical secondary forest setting which allowed exploring the relative importance of climatic and forest structural factors contributing to overall interception loss.

Study area and methods

The present study was conducted within the so-called Corridor Ankeniheny-Zhamena (CAZ) in eastern upland Madagascar as part of the P4GES project (Can paying 4 Global Ecosystem Services values reduce poverty?). The CAZ has a tropical monsoon climate; average annual precipitation is 1625 mm yr-1.

The measurements for this study were carried out in two 0.25 ha forest plots: a semi-mature (ca. 20 years old; BA 35.5 m2 ha-1, LAI,3.39) secondary forest (SMF) and a young secondary forest (YSF, 5–7 years old; BA 6.3 m2 ha-1, LAI 1.83) from 1 October 2014 to 30 September 2015. Throughfall (Tf, mm) was measured daily using 66 non-roving funnel type gauges. In addition, Tf was measured continuously using three V-shaped stainless steel gutters (200 cm x 30 cm x 15 cm each) per forest plot. Stemflow was measured daily on five trees in the YSF and on ten trees in the SMF. Each research plot also has a weather station. Interception losses (I) from the two forests were simulated using the revised analytical model of Gash et al. (1995).

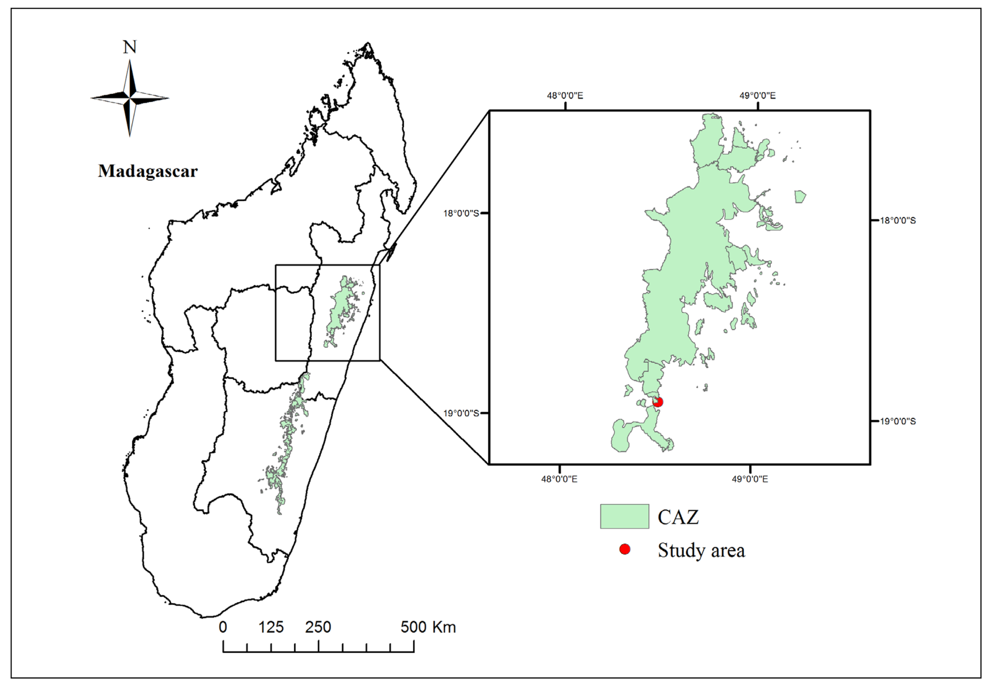

Figure 1: Location of the study sites

Stemflow, throughfall and interception loss

Measured, Tf, Sf and derived I in the semi-mature forest were 71.0%, 1.7% and 27.3% of incident rainfall, respectively. Corresponding values for the young secondary forest were 75.8%, 6.2% and 18.0%. The high Sf for the young forest reflects the strongly upward thrusting habitat of the branches of the dominant species (Psidia altissima) which favours funneling of incident rainfall. The value for I for the semi-mature forest is comparable to values reported for old-growth tropical montane rain forests not affected by fog (28±7%; Bruijnzeel et al., 2011). The value for the younger forest is higher than reported for similarly aged tropical lowland forests. These findings can be explained largely by the prevailing low rainfall intensities (75% arriving at <2.5 mm h-1) and the frequent occurrence of small rainfall events (~70% of the events are <5 mm).

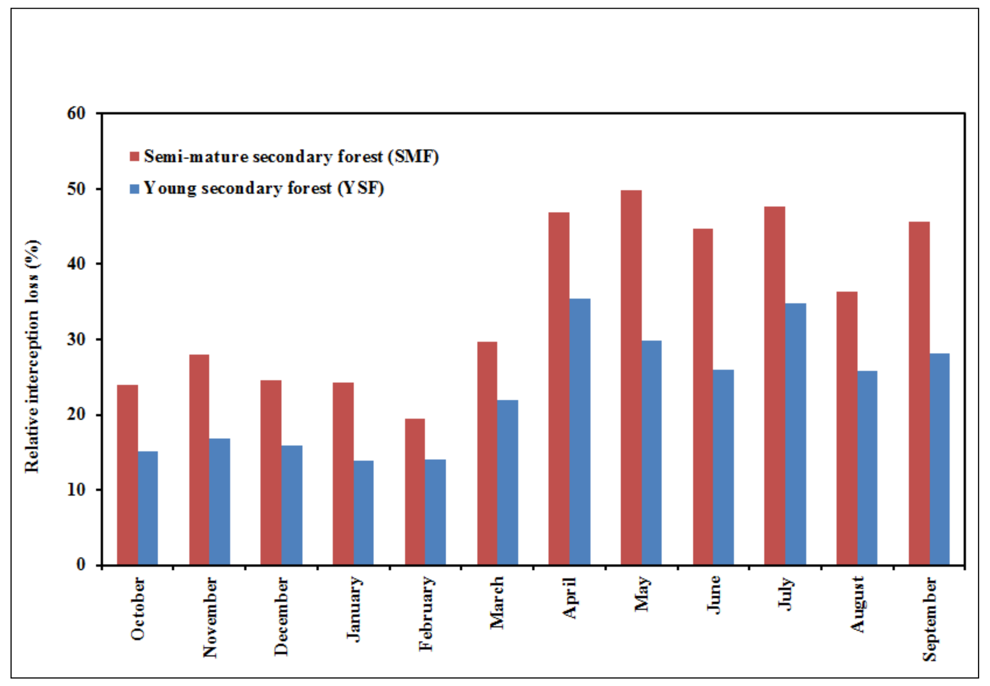

Figure 2: Seasonal variation in the relative interception loss

The analytical model was able to reproduce cumulative I at the two sites and succeeded in capturing the variability in I associated with the seasonal variability in rainfall characteristics, provided that Tf-based values for average wet-canopy evaporation rates (ETF) were used instead of those based on the Penman-Monteith equation (EPM). Optimizing wet-canopy evaporation rates (EOPT) during model calibration had little (YSF) to no (SMF) effect on the overall model performance compared to the results obtained using ETF.

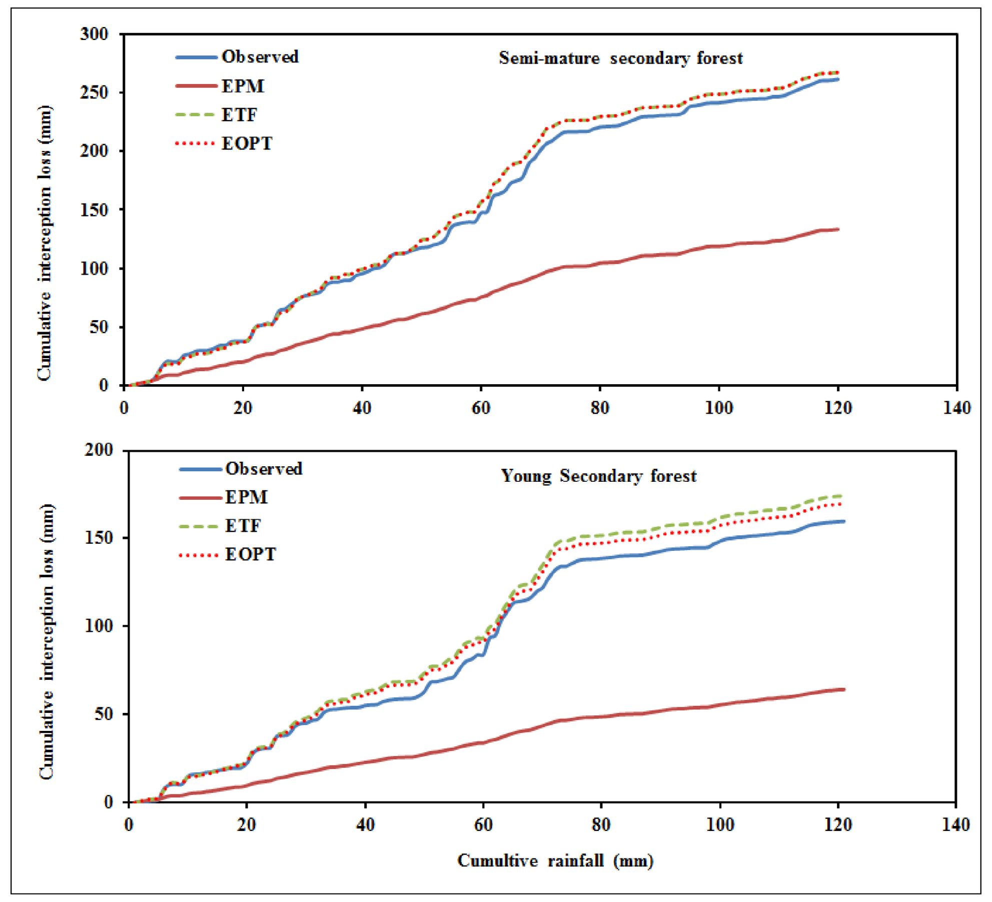

Figure 3: Cumulative measured and modeled interception losses for the calibration data-set

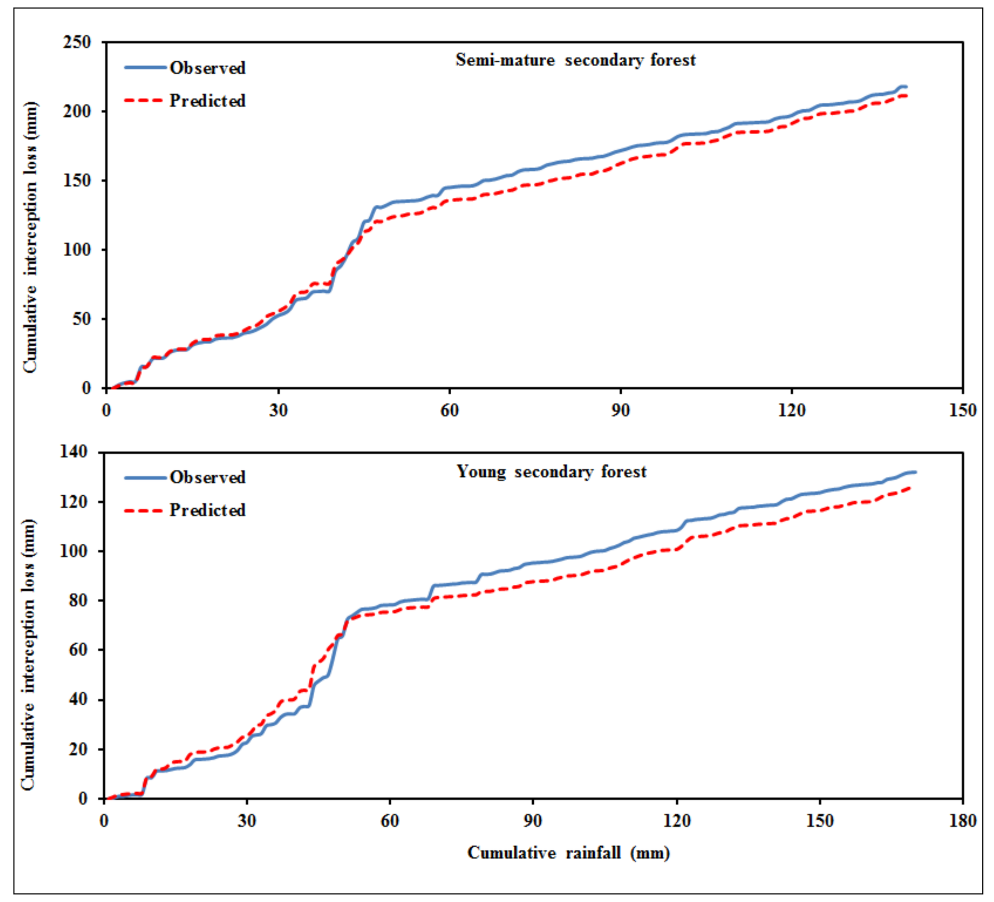

Figure 4: Cumulative measured and modelled interception losses for the validation data-set.

	Calibration data (set1*) Model 1 (*E*PM)		Model 2 (*E*TF)		Model 3 (*E*OPT)		Validation data (set 2*)	
	SMF	YSF	SMF	YSF	SMF	YSF	SMF	YSF
Total gross rainfall (mm)	1048	1027	1048	1027	1048	1027	699	602
Total modeled interception loss (mm)	133	64	267	174	267	170	211	123
Total measured interception loss (mm)	261	159	261	159	261	159	217	132
Modeled-measured (% relative error)	-49	-59.7	2.3	9.4	2.3	6.9	2.7	-6.8
Nash-Sutcliffe model efficiency	0.19	0.05	**0.83**	**0.82**	**0.83**	**0.83**	**0.87**	**0.89**

set1* =Nov, Jan, Feb, May, June; set2* =Oct, Dec, March, April, May, July, Sep

Table 1 A comparison of observed and modelled interception losses (mm) for the two study sites.

Conclusions

1. Given the similarity in climatic conditions for the two stands, the observed differences in interception loss between the two forests can be explained largely by their contrasting structure (notably tree density, height and leaf area index)
2. The model indicated that seasonal variation in the wet-canopy evaporation rate or average rainfall intensity had little or no effect on model performance, as long as the relative evaporation rates did not change.
3. The results indicate that the regenerating tropical secondary forest can re-evaporate an important part of rainfall, which may significantly affect the water balance during certain stages of forest succession after land abandonment.

References

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