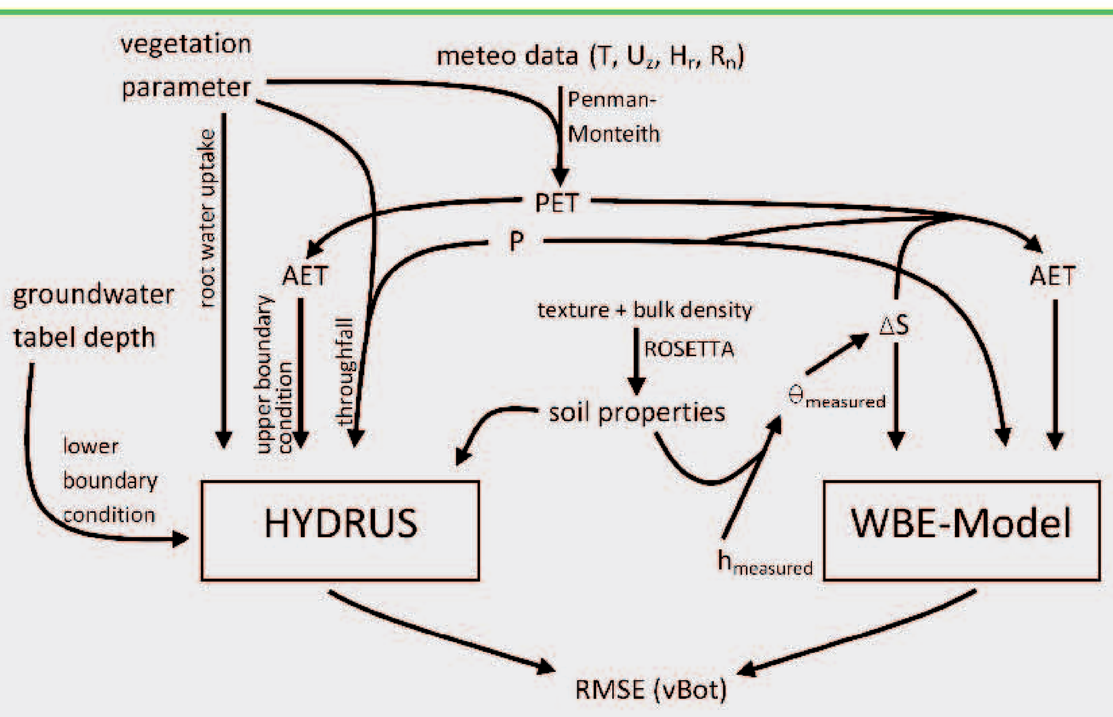
Tree species effects on seepage fluxes in soil in a tropical afforestation

Matthias Sprenger[(1)], S. Wolf[(2)], N. Buchmann[(3)], W. Eugster[(3)], L. Weihermüller[(4)], W. Wilcke[(5)], Y. Oelmann[(6)]

Introduction

Grassland studies indicate that the often recognized positive relation between species diversity and productivity might be caused by complementary water use (Caldeira et al., 2001; Verheyen et al., 2008). To test the transferability with regard to a tropical tree plantation, we i) calculated the seepage flow at plots of one, three, or six tree species with two different approaches and ii) analyzed the effect of the different species and biodiversity levels on the seepage rates.

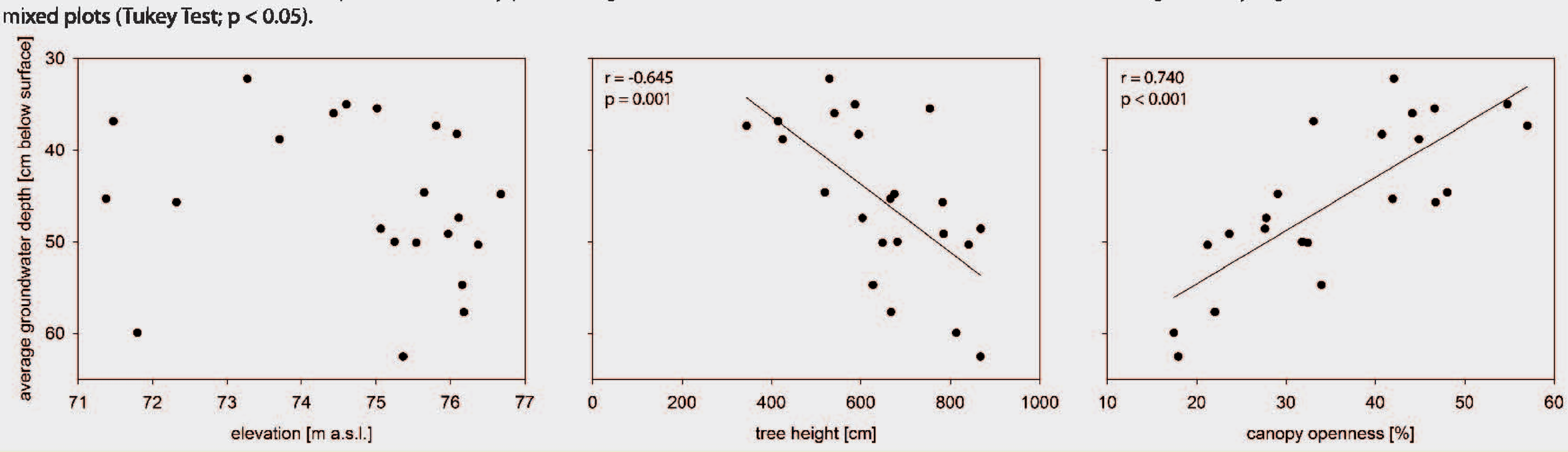


Methods

The analyses were carried out for the wet season in 2008 on plots in Sardinilla (Panama), on which native tree species (*Anacardium excelsum* (AE), *Cedrela odorata* (CO), *Hura crepitans* (HC), *Luehea seemannii* (LS) und *Tabebuia rosea* (TR)) were planted in 2001in monoculture (n = 2 of each species) and in mixtures of three and six species (n = 6 of each). Meteorological, hydrological, pedological, and biological conditions were recorded and the evapotranspiration was calculated with the Penman-Monteith equation. Seepage was calculated on the one hand with the water balance equation (WBE), which considers water inputs, -outputs and changes in the soil water storage, and on the other hand simulated with a physical transport model (HYDRUS-1D).
Differences between the plots were determined by the deviation value $D_{mix} = (O-E)/E$ (Hector et al., 2002), where O is the seepage modeled at a biodiversity plot and E is the smallest seepage rate in monoculture of a species that is included in the particulary biodiversity plot. If $D_{mix} > 0$, then there is more seepage below mixed plots than expected from the monoculture with the smallest seepage rate.

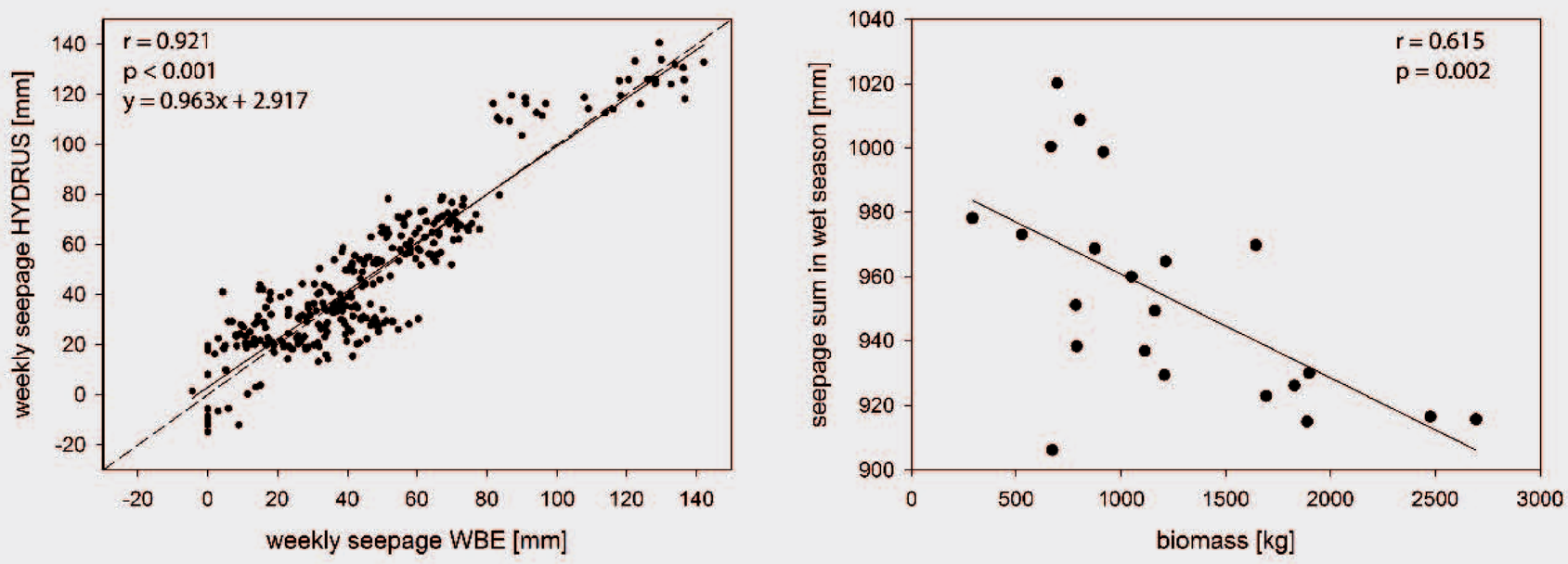
Influence of the vegetation on the groundwater

There was a significant relation between the groundwater levels and tree height and canopy openness during the wet season ($r = -0.645$; $p = 0.001$ and $r = 0.740$; $p < 0.001$, respectively), while the topography had no significant effect on the groundwater level. Therefore, the height and the canopy openness of trees are appropriate parameters to model the water use at different species or diversity plots. The groundwater level and the water content in the soil were significantly higher below monocultures than in **mixed plots (Tukey Test; $p < 0.05$).**

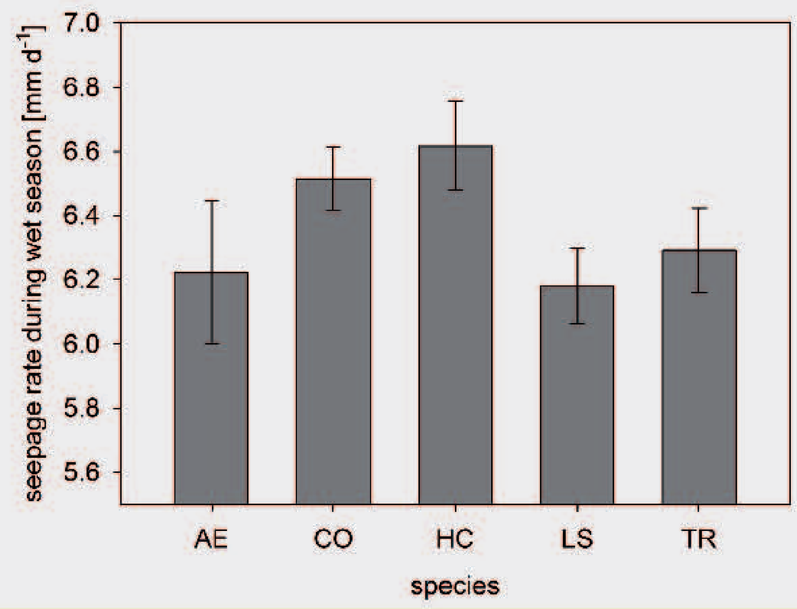


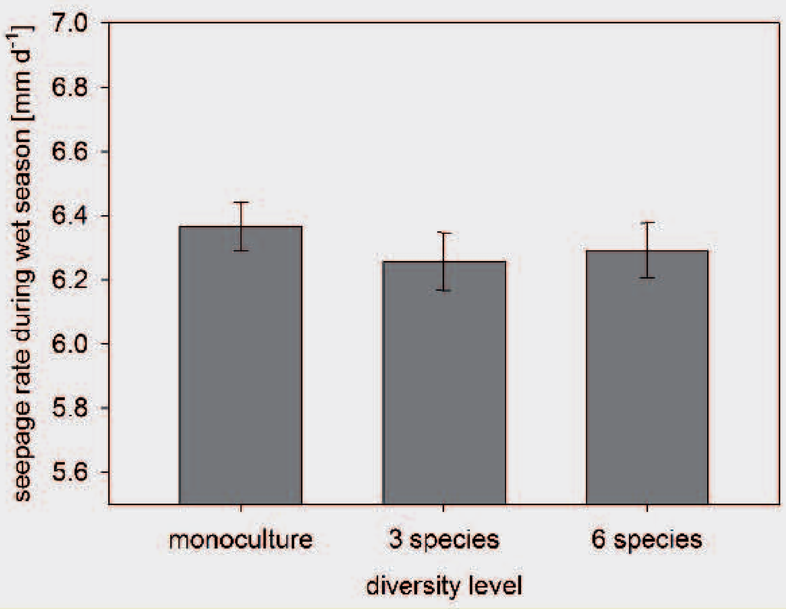
Model comparison

The results of the water balance equation and the physical model with regard to seepage coincide well for all the biodiversity plots ($r = 0.92$; $p < 0.001$). Thus, a simple water balance calculation, which did not account for physical processes in the soil, was suitable to determine the seepage sums. The reasons for the good correlation can be found in i) high and continuous rainfall during the wet season with only minor changes in the water storage term and ii) relative high temporal resolution of the WEB model. Crucial for the seepage rates was therefore the stand biomass, while soil characteristics (e.g. bulk density) were of minor influence.



The influence of vegetation on seepage rates





The HYDRUS-1D simulated seepage rates (± SE) were highest for *Hurea crepitans* (6.69 ± 0.05 mm d^{-1}) and lowest for *Luehea seemannii* (6.23 ± 0.07 mm d^{-1}). Seepage rates of the plots with three and six species were in between with 6.31 ± 0.09 and 6.36 ± 0.08 mm d^{-1}, respectively. The seepage rates were neither significantly different from the monoculture plots below mixed plots of three species nor of six species. Accordingly, an effect of complementary water use in mixtures could not be noticed.

Conclusion

- A water balance approach is sufficent to determine the seepage sums during the tropical wet season.
- The composition of the vegetation does influence the soil water balance.
- Complementary water use in tree species mixtures cannot be noticed.

Literature:
Caldeira, M.C., R.J. Ryel, J.H. Lawton, and J.S. Pereira. 2001. Mechanisms of positive biodiversity-production relationships: insights provided by delta C-13 analysis in experimental Mediterranean grassland plots. Ecol. Lett. 4: 439-443
Hector, A., E. Bazeley White, M. Loreau, et al. 2002. Overyielding in grassland communities: testing the sampling effect hypothesis with replicated biodiversity experiments Ecol. Lett. 5: 502-511Verheyen, K., H. Bulteel, C. Palmborg, et al. 2008. Can complementarity in water use help to explain diversity-productivity relationships in experimental grassland plots? Oecologia 156: 351-361

Thanks to DAAD for PROMOS-Grant and DFG for financing (Wi1601/6-1)

(1) Institute of Hydrology, Albert-Ludwigs-University, Freiburg, Germany (Matthias.Sprenger@hydrology.uni-freiburg.de)
(2) University of California, Berkeley, USA
(3) ETH Zürich, Switzerland
(4) Forschungszentrum Jülich, Germany
(5) University of Bern, Switzerland
(6) University of Tübingen, Germany