

VU Research Portal

Water

Moors, E.J.

2012

document version

Publisher's PDF, also known as Version of record

[Link to publication in VU Research Portal](#)

citation for published version (APA)

Moors, E. J. (2012). *Water*. [PhD-Thesis – Research external, graduation internal, Vrije Universiteit Amsterdam]. *AI Terra Scientific Contributions* 41.

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

E-mail address:

vuresearchportal.ub@vu.nl

Water Use of Forests in the Netherlands

MISSION: Alterra is the main centre of expertise on rural areas and water management in the Netherlands. It was founded 1 January 2000. Alterra combines a huge range of expertise on rural areas and their sustainable use, including aspects such as water, wildlife, forests, the environment, soils, landscape, climate and recreation, as well as various other aspects relevant to the development and management of the environment we live in. Alterra engages in strategic and applied research to support design processes, policymaking and management at the local, national and international level. This includes not only innovative, interdisciplinary research on complex problems relating to rural areas, but also the production of readily applicable knowledge and expertise enabling rapid and adequate solutions to practical problems.

The many themes of Alterra's research effort include relations between cities and their surrounding countryside, multiple use of rural areas, economy and ecology, integrated water management, sustainable agricultural systems, planning for the future, expert systems and modelling, biodiversity, landscape planning and landscape perception, integrated forest management, geo-information and remote sensing, spatial planning of leisure activities, habitat creation in marine and estuarine waters, green belt development and ecological webs, and pollution risk assessment.

Alterra is part of Wageningen University & Research centre (Wageningen UR).

VRIJE UNIVERSITEIT

Water Use of Forests in the Netherlands

ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad Doctor aan
de Vrije Universiteit Amsterdam,
op gezag van de rector magnificus
prof.dr. L.M. Bouter,
in het openbaar te verdedigen
ten overstaan van de promotiecommissie
van de faculteit der Aard- en Levenswetenschappen
op dinsdag 22 mei 2012 om 15.45 uur
in de aula van de universiteit,
De Boelelaan 1105

door

Eduardus Johannes Moors

geboren te Dakar, Senegal

promotoren: prof.dr. A.J. Dolman
prof.dr. R.A. Feddes

Leescommissie: Prof. Dr. R.J.M. Ceulemans
Dr. J.H. Gash
Prof. Dr. P. Kabat
Prof. Dr. Ir. R. Uijlenhoet
Dr. M.J. Waterloo

“Why am I standing in the middle of nowhere, standing here with nothing to do?”
(free after Caro Emerald)

Cover page: Artist impression by Almas Pieters (www.gestikt.nl).

The research presented in this publication was conducted at Alterra in Wageningen and Vrije Universiteit Amsterdam, the Netherlands.

Moors, Eddy J.

Water Use of Forests in the Netherlands, PhD-thesis Vrije Universiteit Amsterdam, the Netherlands. 290 p.

Moors, Eddy J.

Water Use of Forests in the Netherlands, Alterra Scientific Contributions 41, Alterra, part of Wageningen UR, the Netherlands. 290 p.

ISBN 978-90-327-0398-1

©2012 E.J. Moors Text, figures and photographs unless otherwise credited

All rights reserved. No part of this publication may be reproduced in any form without the written consent of the author or copyright owner.

Abstract

Forests are complex ecosystems with a large variability in the horizontal as well as in the vertical space. To study the dissimilarities in water use for different forest types, the water and energy balance of five forest stands in the Netherlands were observed during periods varying from two years to more than 15 years. The main tree species of the stands were: Scots pine, poplar, oak, larch and at one site a mixture of pine, birch, beech and oak.

Two conditions were distinguished for the analysis of the driving processes of the evaporation rate: dry and wet. Under dry conditions the opening and closing of the stomatal conductance was the main process controlling the evaporation rate. The drivers controlling the opening and closing were different between tree species and for undergrowth and tree species. Overall the most important driver was the vapour pressure deficit. The inclusion of temperature did not improve the optimization results and it is advised not to include temperature as a driver to simulate the stomatal conductance for the present climatic conditions in the Netherlands. The contribution of the undergrowth varied with time between 5% and 100% during the year. The smallest contribution of the undergrowth to the total evaporation appeared in the middle of the summer. The highest contribution appeared in spring and autumn.

To improve the feedback of water stress by lowering groundwater tables during prolonged periods of drought a conceptual model is introduced incorporating two separate soil water signals. The model has a default feedback based on the water content at the deepest roots, and a site specific feedback through the soil water content of the surface layer containing 80 to 90% of all roots. The default feedback is based on data of multiple forest stands over Europe.

Under wet conditions it is shown that the evaporation at the end of the shower and just after the shower is much larger than often assumed. In most models this

underestimation of the evaporation rate of intercepted water is compensated by an under estimation of the water storage capacity of the leaves. The evaporation rate under wet conditions is better simulated by taking into account the vertical variation in the surface roughness lengths for heat and momentum.

Keywords: Forest, undergrowth, hydrology, evaporation, interception, drought, root water uptake.

Preface

So how did I get involved in writing this thesis? In most cases decisions largely depend on opportunities and contacts coming together. In my case I would like to acknowledge Reinder Feddes, who phoned me on a Saturday evening and introduced me to Han Dolman. Han was then looking for staff to work on the project “Hydrology of forests and forested areas in the Netherlands” (*Forest Hydrology Project*). This project was the starting point for my research and this thesis. Reinder Feddes together with Jon Wieringa became my promoters and Han Dolman my daily advisor. After Jon Wieringa retired, Han Dolman became my promoter together with Reinder Feddes. I want to express my gratitude to my team of promoters. Both Han Dolman en Reinder Feddes have been especially supportive and instrumental not only in starting up this study, but also in finally getting it finished. Han and Reinder, thank you very much!

The study started with the *Forest Hydrology Project* that was initiated in 1994 by the Ministry of Agriculture, Nature and Food Quality of the Netherlands and implemented by the The Winand Staring Centre (this later became Alterra-Wageningen UR). Financially this project was made possible not only by the Ministry of Agriculture, Nature and Food Quality, but also by VEWIN, “Staatsbosbeheer”, “Natuurmonumenten” and “Unie van Landschappen”. Wim Zeeman played a crucial role in mobilizing all these partners. The data collected for this project are the basis for the present thesis. Representatives of the organizations financially supporting the project as well as a number of representatives from scientific organization were member of the advisory board of the project.

I would like to thank the members of the advisory board of the *Forest Hydrology Project* for their feedback and advice during the first years 1994-1998 of this study:

- ir. J.M. Brand (directie Natuur, Ministerie van Landbouw, Natuurbeheer en Visserij);

-
- ir. G. van Tol (IKC, Natuur);
 - dr. ir. W. Bouten (Universiteit van Amsterdam);
 - Prof. A.W.L. Veen (Rijksuniversiteit van Groningen);
 - ir. H.K.A. Rotermundt (NUON, representing VEWIN);
 - ir. W.P.C. Zeeman (Staatsbosbeheer);
 - ir. K. Voetberg (Natuurmonumenten);
 - ir. H. Massop (Unie van Landschappen);
 - J. Deurloo (Waterschap Regge en Dinkel).

To enlarge the number of forest types included in this study, an additional site, i.e. the Edesebos site, was added. The team of the Winand Staring Centre collecting the data at this site was lead by Marja Ogink-Hendriks from 1988-1990. After the end of the forest hydrology project, all sites except the Loobos site were dismantled.

In 1996 after the CO₂-flux measurements were started in the pine forest of Loobos, the Loobos site became part of the international flux database FLUXNET (www.fluxnet.ornl.gov). At the moment the Loobos site is world wide one of the sites with the longest record of evaporation, sensible heat and CO₂ flux data. This international collaboration was made possible with financial support of national and international projects, such as:

- Research program on Climate Change of Wageningen UR (Min. of Agriculture, Nature and Food Quality, NL);
- Integrated observations and modelling of greenhouse gas budgets at the ecosystem level in the Netherlands (Climate for Spatial Planning, NL);
- EuroFlux (DG Research, EU);
- CarboEurope (DG Research, EU);
- GHG-Europe (DG Research, EU).

Before the measurements for the *Forest Hydrology Project* could start, sites had to be selected. Together with Han Dolman we spent hours of driving around the country looking for the ultimate site with an almost unlimited fetch, i.e. the same forest type as far as the eye reaches. Finding such a site was not an easy task. By the time we thought we had found an excellent location, we often discovered that

without knowing we had crossed the border and were either in Belgium or Germany. Nevertheless, we managed to find a set of sites that fulfilled our purposes.

Many thanks I want to express also to the staff of the organizations managing the forests such as “Staatsbosbeheer”, “Natuurmonumenten” and “Unie van Landschappen”. They not only provided access to the sites, but also shared their knowledge and helped us with typical field work such as pulling Landrovers out of the mud and setting up fences to keep the wild ponies away.

Together with Jan Elbers, Han Dolman and Wim Sijnders the measurement set-up was designed and measurement towers up to a height of 27 m were erected at each of the four sites. Especially Jan’s expertise in designing and constructing automatic measurement set-ups was very helpful. Jan and Wim were also heavily involved in the maintenance of the sites, equipment calibration, data quality checking, and all other work that is needed to maintain a number of continuous monitoring sites at remote locations. Special moments were the visits during Christmas together with Jan when the forests were very quiet and covered with snow.

Later Wilma Jans joined our group. Wilma together with Santi Sabaté was also responsible for the sapflow measurements collected at the Loobos site and used for validation purposes.

Of course it was impossible to collect and process all the data used in this thesis by myself. Fortunately, a large number of people were willing to contribute in numerous ways and by doing this enabled me to write this thesis.

Mark Ashby was one of the persons with whom the SWAPS model was developed. A number of the concepts as are used in this thesis were implemented in this model. The people working on the unsaturated zone model SWAP also deserve my thanks as the soil water flow of the SWAPS model is based on the concepts of the SWAP model. I would also like to thank Niall Hanan for his work on the sparse canopy light interception scheme for the SWAPS model. The Bankenbos site was much closer to Groningen than to Wageningen. Therefore, I am thankful that Henk de Groot, Jan van de Burg and Peter van Breugel were willing to assist us in the maintenance of this site. Marja Ogink-Hendriks (data collection and analysis of the Edesebos site), Marlies Hamaker (leaf area analysis of all needles), Erik van der Elzen (design electrical circuits), Gerard Veldman (soil sample analysis), Han te Beest (installation of the discharge structures and groundwater observation tubes), Lara Prihodko (reading groundwater levels of the observing tubes), Iwan Supit (proof reading a part of my thesis), Obbe Tuinenburg (LaTeX problem solver), Almas Pieters (cover design) and my two paranymphs Wies Nijman-Moors and Saskia Werners. I am aware that there are people whom I did not mention here, but I want you to be assured that I have much appreciated all your help.

During the years that passed since the start of my thesis a large number of people

in- and outside of Wageningen were always showing interest, providing moral support and willing to help if needed. Just to name a few: Pavel Kabat, Cor Jacobs, Bart Kruijt, Ronald Hutjes, Herbert ter Maat, Saskia Werners, Judith Klostermann, Annemarie Groot, Philip Hamaker, Catharien Terwisscha van Scheltinga, Laurens Ganzeveld, Petra Stolk, Jeroen Veraart, Nies Springer, Gerard Oosterbaan, Wim Cofino, and all other members of the groups I have had these years the privilege to work with, i.e. Water Atmosphere and Substances, Land Atmosphere Interactions, Earth System Sciences & Climate Change. Also the contacts with the national and international Flux-community was highly appreciated during these years.

An absence of four months made possible by Alterra, allowed me to make significant progress towards finishing my thesis. This time was spent in Amsterdam and I am very grateful for the hospitality of the people at the Eco-hydrology Group of “Vrije Universiteit van Amsterdam”. Special thanks goes to Maarten Waterloo, Michiel van der Molen and Margriet Groenendijk for their warm welcome and the great opportunities not only to discuss scientific issues, but also to solve technical problems using analysis- and word processing software.

The work of the reading committee is at the end of a thesis. I thank all members of the reading committee for their time and comments.

Finally I would like to thank all my family and especially my parents Wim, Gerda, Frits and Ellen for their continuous support throughout my thesis.

Although the data collection was done as part of my work at Alterra, the analyses and writing was done mostly in the evenings, weekends and holidays. Niek, Céline and last but not least Franciska many many thanks for your help, support and your patience during all those years.

Eddy J. Moors
Opheusden, February 2012