

# Contents

<b>1. Introduction and synthesis</b>	<b>1</b>
1.1. General introduction	1
1.1.1. Climate change and its impacts on forests and hydrology	1
1.1.2. Forest-water interactions in temperate and cold forests	3
1.1.3. Modeling the vegetation-hydrology interface	4
1.2. Research goals and questions	7
1.3. Summary of results	8
1.4. Synthesis	12
<b>2. Quantifying and modeling water availability in temperate forests: A review of drought and aridity indices</b>	<b>21</b>
2.1. Introduction	22
2.2. Definitions	23
2.3. Drought and aridity effects on trees and forests	24
2.4. A classification of drought and aridity indices	27
2.4.1. Precipitation-based indices	27
2.4.2. Inclusion of evaporative demand	29
2.4.3. Inclusion of soil moisture storage	30
2.4.4. Inclusion of vegetation properties	33
2.4.5. Inclusion of physiological properties	34
2.4.6. Variations	36
2.5. Intercomparisons and evaluations of drought and aridity indices	36
2.6. Water availability indices in dynamic forest models	42
2.7. Current debates and open questions	44
2.7.1. The role of VPD for physiological drought	44
2.7.2. Suitability of drought indices under climate change	45
2.8. Synthesis and conclusions	46
<b>3. Sensitivity of forest water balance and physiological drought predictions to soil and vegetation parameters – A model-based study</b>	<b>59</b>
3.1. Introduction	59
3.1.1. Forest–water interactions and modeling them	60
3.1.2. Sensitivity analysis in hydrological and environmental modeling	62
3.1.3. Aim of this work	63
3.2. Methods	64
3.2.1. The water balance FORHYTM	64

3.2.2. Sensitivity analysis	69
3.2.3. Data	72
3.3. Results	75
3.3.1. Screening analysis	75
3.3.2. Meta-model based sensitivity analysis	75
3.4. Discussion	85
3.4.1. Screening of unimportant parameters	85
3.4.2. Parameter effects	85
3.4.3. Implications for model development	87
3.4.4. Links to the Budyko framework	88
3.4.5. Limitations of this study and outlook	89
3.5. Conclusions	90
3.A. Extended Methods	92
3.A.1. Model details	92
3.A.2. Details on the sensitivity analysis	95
3.B. Extended results	100
3.B.1. Statistical meta-models: model structure	100
3.B.2. Plausibilization of FORHYTM model output	100
<b>4. Testing an optimality-based model of rooting zone water storage capacity in temperate forests</b>	<b>113</b>
4.1. Introduction	114
4.2. Methods	116
4.2.1. Guswa's optimal rooting depth models	116
4.2.2. $S_r$ estimated through model calibration	121
4.2.3. Uncertainty and sensitivity analyses	124
4.3. Results	126
4.3.1. Calibrated $S_r$ estimates	126
4.3.2. Climate characteristics of the selected FLUXNET sites	129
4.3.3. $S_r$ parameterization	129
4.3.4. Parameter sensitivity of G-For10 and uncertainty of $S_r$ estimates	130
4.3.5. Effect of $S_r$ estimates on model performance	133
4.4. Discussion	136
4.4.1. Calibrated $S_r$ and their uncertainty	136
4.4.2. Behavior of the optimal rooting depth models	137
4.4.3. Theoretical considerations	140
4.4.4. Implications for model development	141
4.5. Conclusion	144
4.A. List of symbols	145
4.B. FORHYTM model description and validation results	145
4.C. Additional figures	151

<b>5. FORHYCS: A spatially distributed model combining hydrology and forest dynamics</b>	<b>177</b>
5.1. Introduction	178
5.1.1. Coupled models of hydrology and forest dynamics	179
5.1.2. Aims of this work	181
5.2. Methods and Data	182
5.2.1. FORHYCS model description	182
5.2.2. The Navizence case study	190
5.3. Results	196
5.3.1. Plausibilization of simulated streamflow	196
5.3.2. Forest spin-up with different model configurations	199
5.3.3. Idealized climate change runs	204
5.4. Discussion	209
5.4.1. Effect on hydrological simulations	209
5.4.2. Effect on forest simulations	211
5.4.3. Effect of coupling on model behavior under climate change	212
5.4.4. Effect of additional processes	212
5.5. Conclusions and Outlook	213
5.A. Species-specific drought tolerance parameter values	214
5.B. Extended methods	216
5.B.1. Phenology module	216
5.B.2. Effect of low temperature in TreeMig	220
5.B.3. Local water balance module	221
5.B.4. Comparison of soil water storage capacity datasets	223
5.B.5. PREVAH parameterization	223
5.C. Extended results	225
<b>A. CV</b>	<b>247</b>