



HAL
open science

Modeling water availability for trees in tropical forests

Fabien Wagner, Bruno Hérault, Clement Stahl, Damien Bonal, Vivien Rossi

► **To cite this version:**

Fabien Wagner, Bruno Hérault, Clement Stahl, Damien Bonal, Vivien Rossi. Modeling water availability for trees in tropical forests. 25. International Biometric Conference, Dec 2010, Florianopolis, Brazil. 16 p. hal-01032104

HAL Id: hal-01032104

<https://hal.science/hal-01032104>

Submitted on 6 Jun 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Modeling water availability for trees in tropical forests

Fabien Wagner¹, Bruno Herault¹, Clement Stahl², Damien Bonal³
Vivien Rossi⁴

¹Université Antilles-Guyane, UMR 'Ecologie des Forêts de Guyane', French Guiana;

²INRA, UMR 'Ecologie des Forêts de Guyane', French Guiana

³INRA, UMR INRA-UHP 1137 'Ecologie et Ecophysiologie Forestière', France;

⁴CIRAD, UMR 'Ecologie des Forêts de Guyane', French Guiana

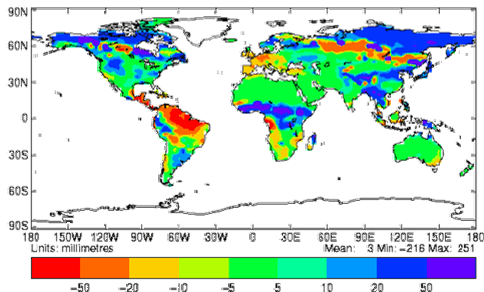


outline

- 1 background
- 2 the model
- 3 results
- 4 summary/future works

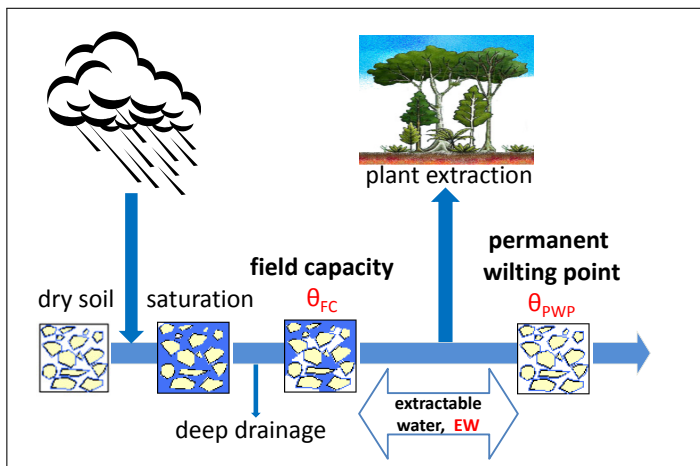
why modelling water availability in tropical forest ?

- ▶ tropical forests are subject to a dry season, incl. Amazon Basin
- ▶ climate modeling scenarios, Hadley center, change in annual soil water content for the late XXIth



- ▶ need for developing soil water availability model for tropical forests

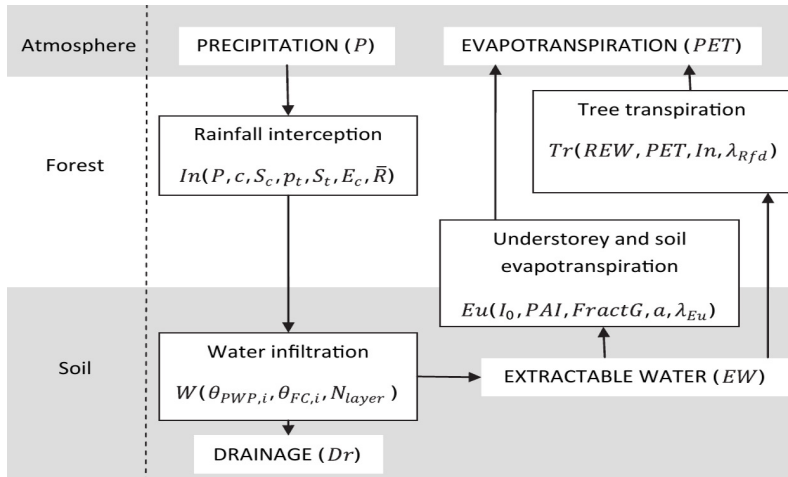
soil water cycle model



- ▶ Relative Extractable Water: $REW = \frac{EW}{EW_{MAX}}, \in [0, 1]$

soil water balance model

► $\Delta EW = P - In - Tr - Eu - Dr$



water infiltration

- ▶ soil layers
 - soil = succession of 1cm layers
 - each layer has a θ_{PWP} a θ_{FC} and a % of roots
 - estimates of θ_{PWP} and θ_{FC} in the calibration

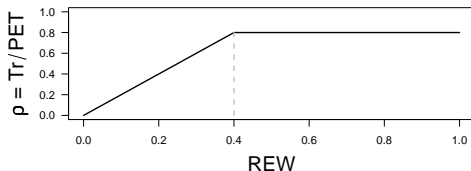
- ▶ water dynamics
 - water > field capacity in a layer \implies water fills the next layers
 - water remains after the last layer \implies lost by deep drainage

▶ REW

$$\bullet \text{REW}_d = \underbrace{\sum_{l=1}^{N_{\text{layer}}} \left(\frac{\widehat{EW}_{l,d} - \theta_{PWP,l}}{\theta_{FC,l} - \theta_{PWP,l}} \right)}_{\text{REW}_{\text{layer}}} \times \underbrace{\sum_{l=1}^{N_{\text{layer}}} Rfd_l}_{\text{layer roots \%}}$$

tree transpiration

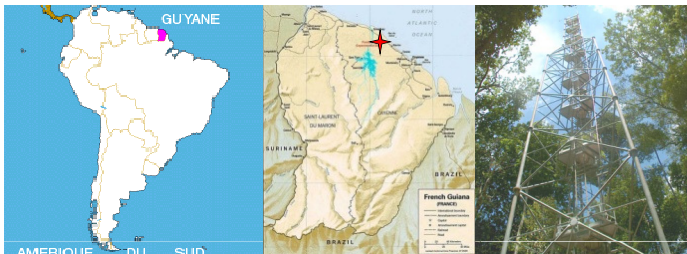
▶ computation



▶ tree transpiration extraction

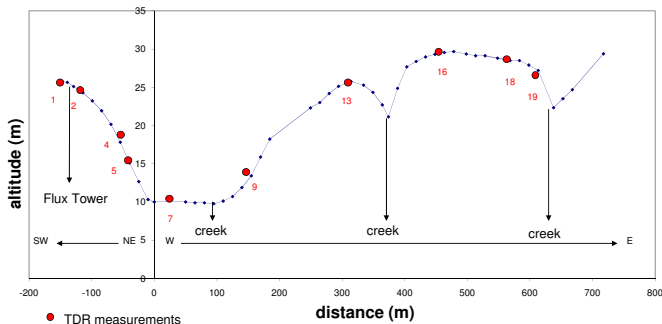
- fine root density (Rfd) \implies exponential function
- $Rfd(depth) = \lambda_{Rfd} \times \exp(-\lambda_{Rfd} \times depth)$
- $Rfd_l = \int_{depth_{l-1}}^{depth_l} Rfd(depth) ddepth$
- $Tr_{l,d} = \rho_l \times PET \times (1 - \exp(-\lambda_{Rfd} \times N_{layer})) \times Rfd_l$

calibration data



- ▶ site : Paracou experimental site, French Guiana
- ▶ meteorological data : Guyaflux, flux tower, since 2003

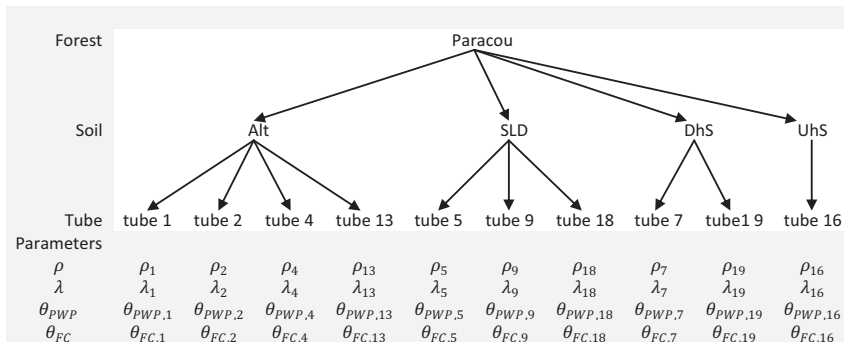
calibration data



- ▶ soil moisture measurement : 10 tubes on 4 soil types, TDR probe measurements from 20 to 260 cm by 20, since 2004
- ▶ automatic stem growth measurements: 6 dominant trees

model parameters and inference

► nested structure of the model



model parameters and inference

- ▶ stochasticity of the model : normal error of the probe
- ▶ likelihood of the model

$$\begin{aligned} \mathcal{L}(\text{Data}|\Theta_m) &= \prod_{p=1}^{N_{tube}} \mathcal{L}(\text{Data}_p|\Theta_m) \\ &= \prod_{p=1}^{N_{tube}} \prod_{d=1}^{N_{day}} \prod_{l=1}^{N_{layer}} \frac{\exp\left[-\frac{(\widehat{EW}_{l,d}^p - EW_{l,d}^p)^2}{2(0.2 \times EW_{l,d}^p)^2}\right]}{\sqrt{2\pi(0.2 \times EW_{l,d}^p)}} \end{aligned}$$

- ▶ $\widehat{EW}_{l,d}^p$ are the predicted extractable water values

Metropolis-Hastings within a Gibbs algorithm

generation of a candidate θ_k^* and the new vector of parameters Θ^* :

$$\begin{aligned}\theta_k^* &\sim \pi_{\theta}^{prop}(\theta_k^{n-1}) \\ \Theta^* &= \left\{ \theta_1^{n-1}, \dots, \theta_{k-1}^{n-1}, \theta_k^*, \theta_{k+1}^{n-1}, \dots, \theta_{Npar}^{n-1} \right\}\end{aligned}$$

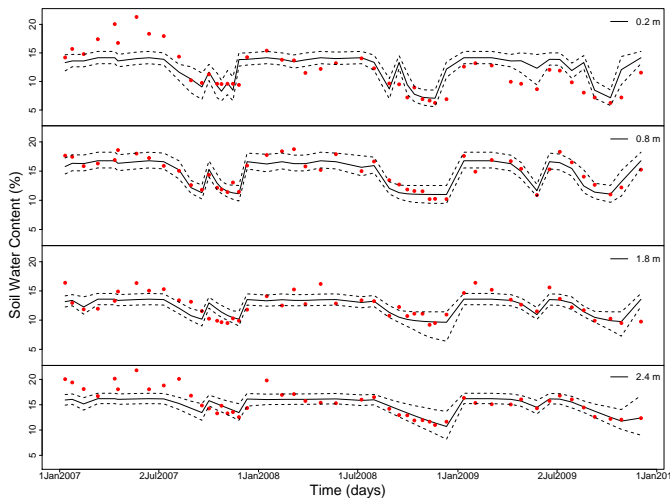
acceptation or rejection of the new candidate θ_k^* by computing the ratio of the likelihood :

$$\gamma = \underbrace{\frac{\mathcal{L}(\text{Data}|\Theta^*)}{\mathcal{L}(\text{Data}|\Theta^{n-1})}}_{\text{likelihood}} \times \underbrace{\frac{\pi_0(\theta_k^*)}{\pi_0(\theta_k^{n-1})}}_{\text{prior}} \times \underbrace{\frac{\pi_{\theta}^{prop}(\theta_k^{n-1}|\theta_k^*)}{\pi_{\theta}^{prop}(\theta_k^*|\theta_k^{n-1})}}_{\text{proposal}} \wedge 1$$

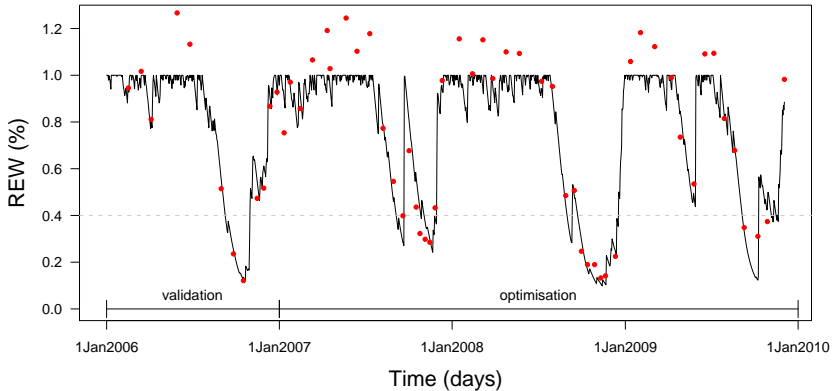
the candidate θ_k^* is accepted or rejected as follows :

$$u^t \sim \mathcal{U}_{[0,1]}, \quad \theta_k^n \begin{cases} \theta_k^* & \text{if } \gamma \geq u^t \\ \theta_k^{n-1} & \text{if } \gamma < u^t \end{cases}$$

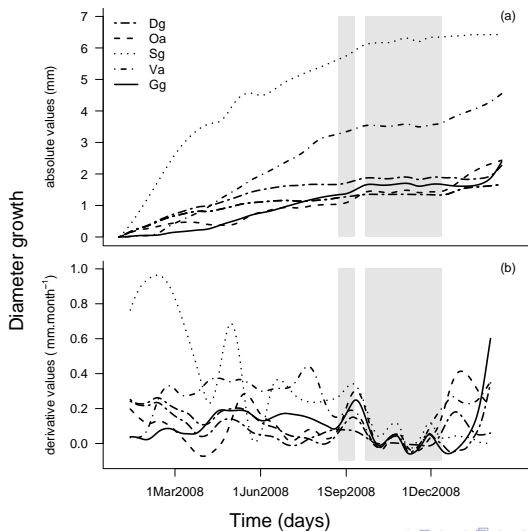
model predictions: soil water content



model predictions: REW, relative extractable water



REW and tree growth



▶ summary

- 1 the method achieve to reproduce the daily extractable water
- 2 new method to estimate field capacity and permanent wilting point
- 3 new method to model roots functioning in soil water balance model

▶ perspectives

- 1 history of the soil water availability
- 2 linking REW to long-term follow up of tropical forest dynamics
- 3 REW 0.4 threshold for tropical forest species

