Full-rotation carbon, water and energy fluxes in a tropical eucalypt plantation

Yann Nouvellon, José-Luiz Stape, Guerric le Maire, Jean-Marc Bonnefond, Joannès Guillemot, Mathias Christina, Jean-Pierre Bouillet, Otavio Camargo Campoe, Jean-Paul Laclau, et al.

Introduction

Eucalyptus plantations in Brazil

- 3.5 millions ha in 2006
- 5.7 millions ha in 2016
- Mostly for cellulose, and charcoal (steel industry)

1 year

3 years

6 years

Plantation

Clear cut

Tree height (m)

Root depth (m)

25
20
15
10
5
0
-5
-10
-15
-20

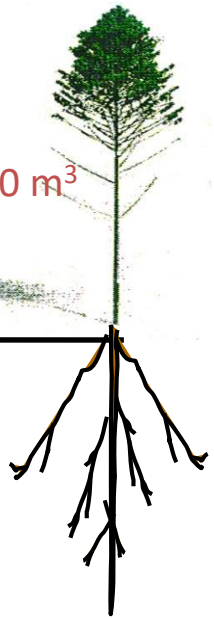
0
10
20
30
40
50
60
70
80

Stand age (month)

Christina et al., 2011

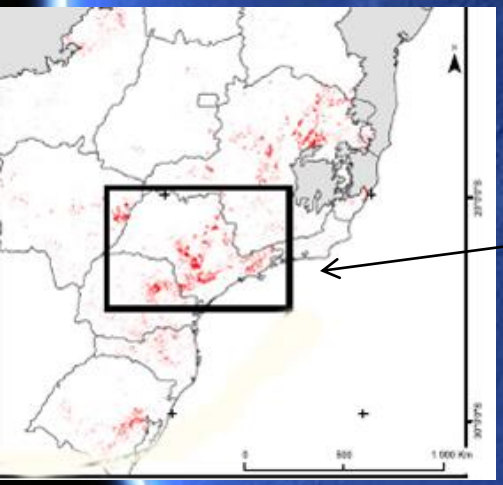
Main reasons for their success:

- High yields despite highly weathered tropical soils (~40 -50 m^3 ha^{-1} yr^{-1})
- Ability to grow as coppice



Objectives:

- Long-term monitoring of carbon, water and energy budgets over Eucalyptus grandis plantations in Brazil;
- Improve our understanding of eucalypt plantation functioning, quantify resource use and efficiencies, develop and validate models …



le Maire et al.,2014. Mapping short-rotation plantations at regional scale using MODIS time series: Case of eucalypt plantations in Brazil . Remote Sensing of Environment 152:136–149.

- Itatinga
- State of Sao Paulo
- Elevation: 850 m
- Rainfall: 1360 mm (long-term average)
- Air temperature~20°C
- Deep sandy soils
- *Eucalyptus grandis*

Jan 2008 Sept 2009 Nov 2009 Rotation length = 7 yrs Dec 2016

Rotation 1 (Eucalytus grandis)

Rotation 2 (E. grandis * E. urophylla)

In this presentation: 9 yrs of eddy-covariance measurments:
~2 yrs before clearcut and 7 yrs after

Clearcut

Replanting

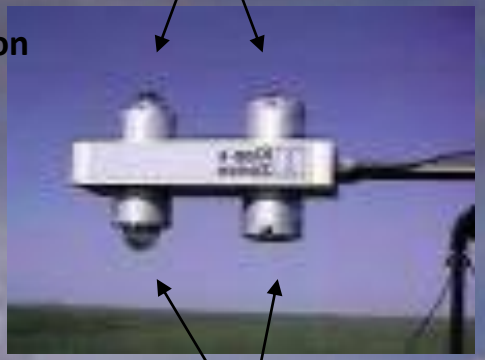
Objectives:

- Effects of clear cut;
- Changes over the rotation (stand age)

Meteorological station + eddy-covariance system

Incident Shortwave and long-wave radiation

Net radiation



Rainfall

LI7500
[CO2], [H20], 20hz

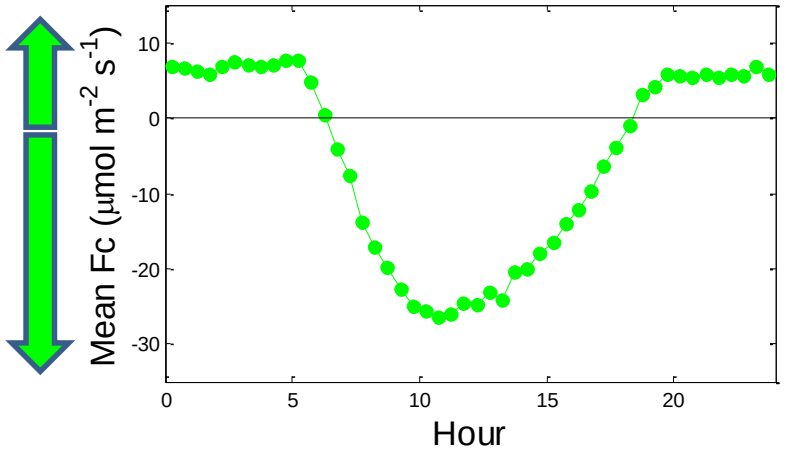
3D Sonic anemometer
U, V, W, T (20Hz)

Reflected Shortwave and outgoing longwave radiation

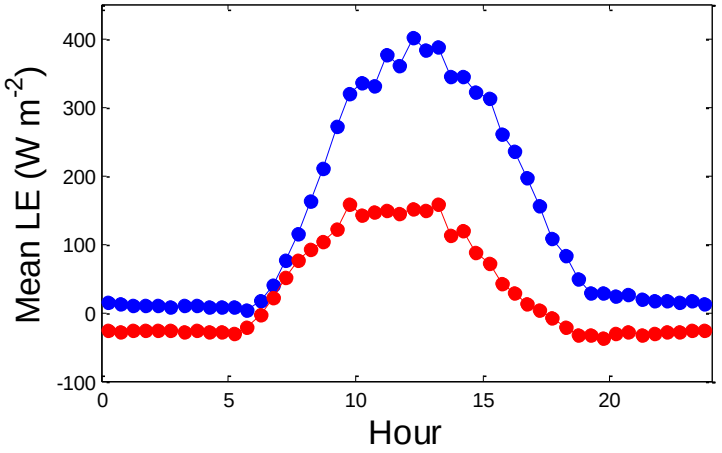
Diffuse PAR, Direct PAR, Total PAR

Wind speed, Tair, Air relative humidity

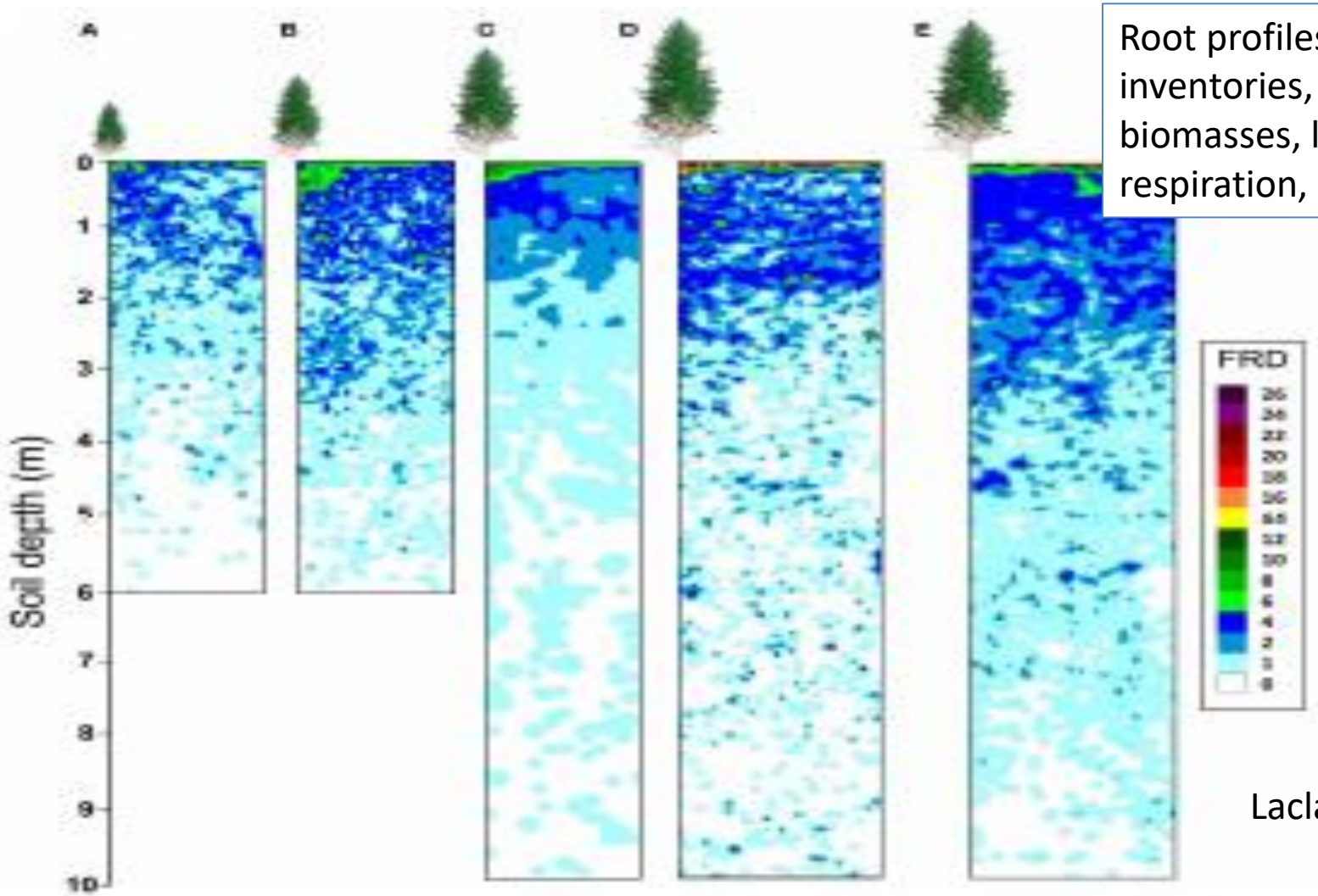
Semi-hourly measurents



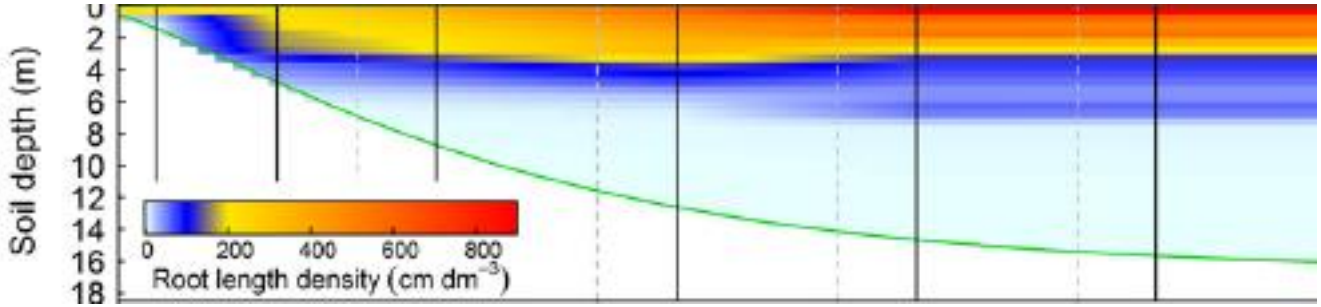
Latent and sensible heat fluxes



Root profiles, frequent inventories, destructive biomasses, litterfall, soil respiration, etc.

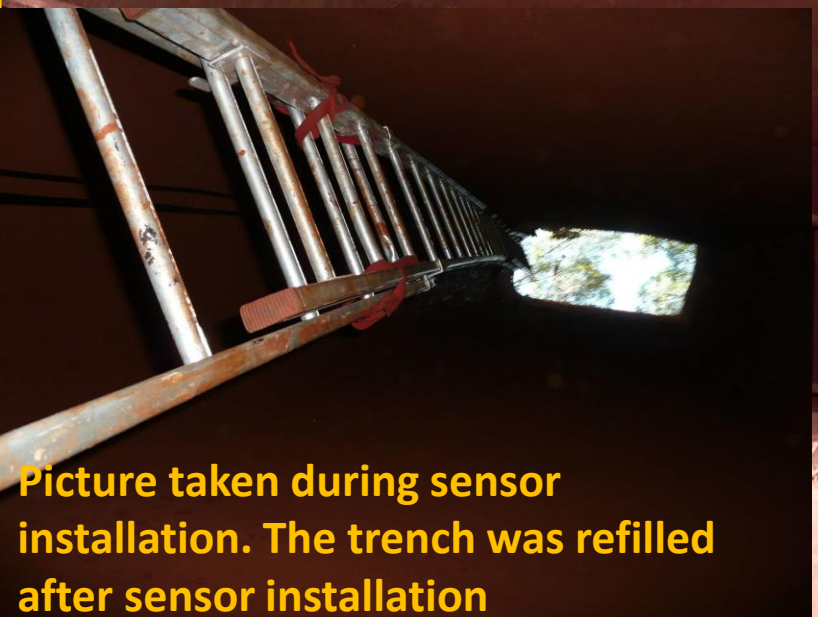


Laclau et al., 2013



Christina et al., 2017

Soil water content measurments till 10 m deep in several trenches



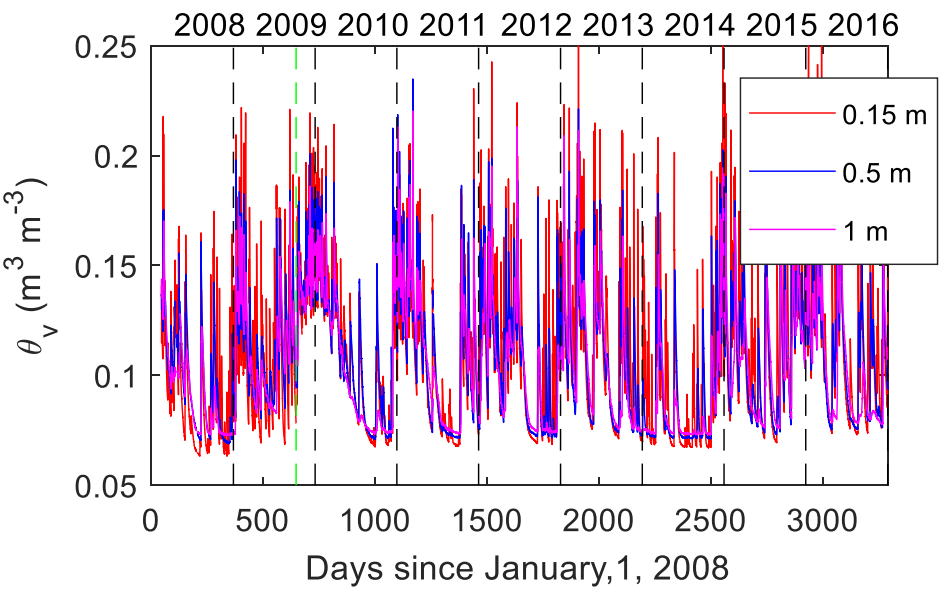
Picture taken during sensor installation. The trench was refilled after sensor installation

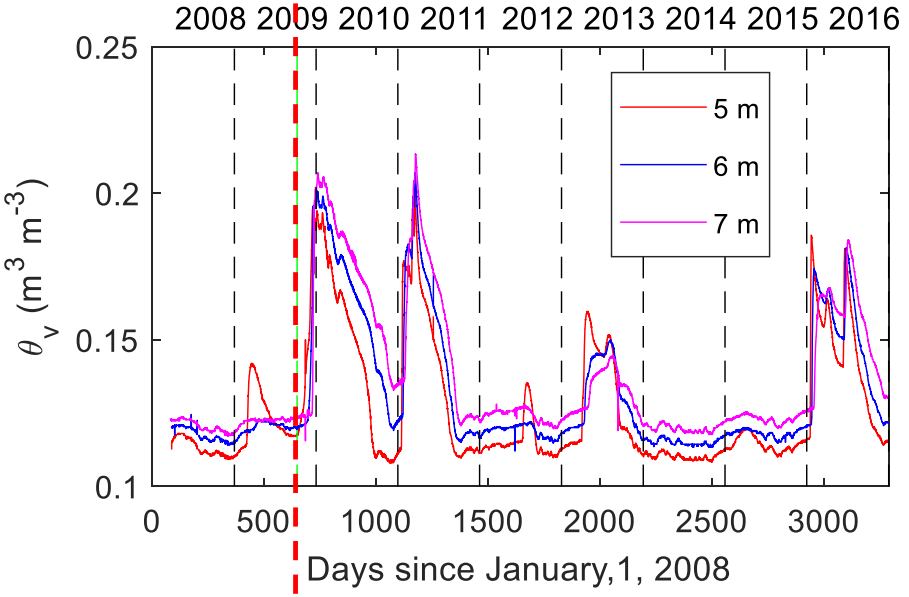
Monitoring of water table depth

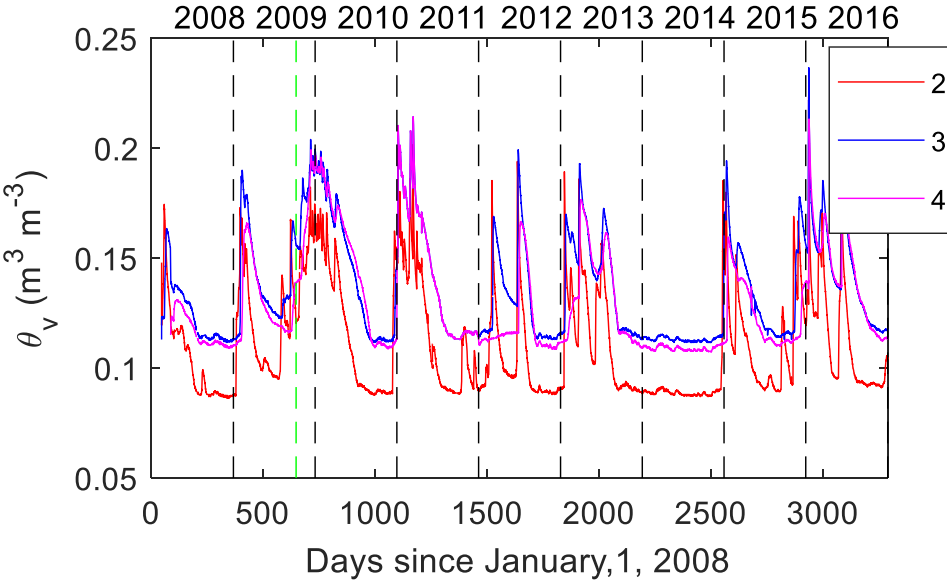
Results

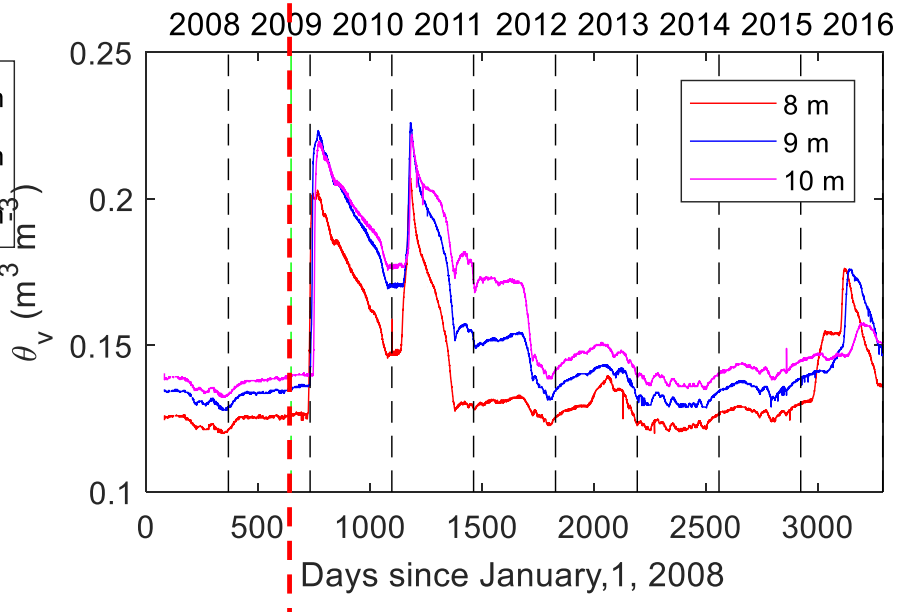
Clearcuting

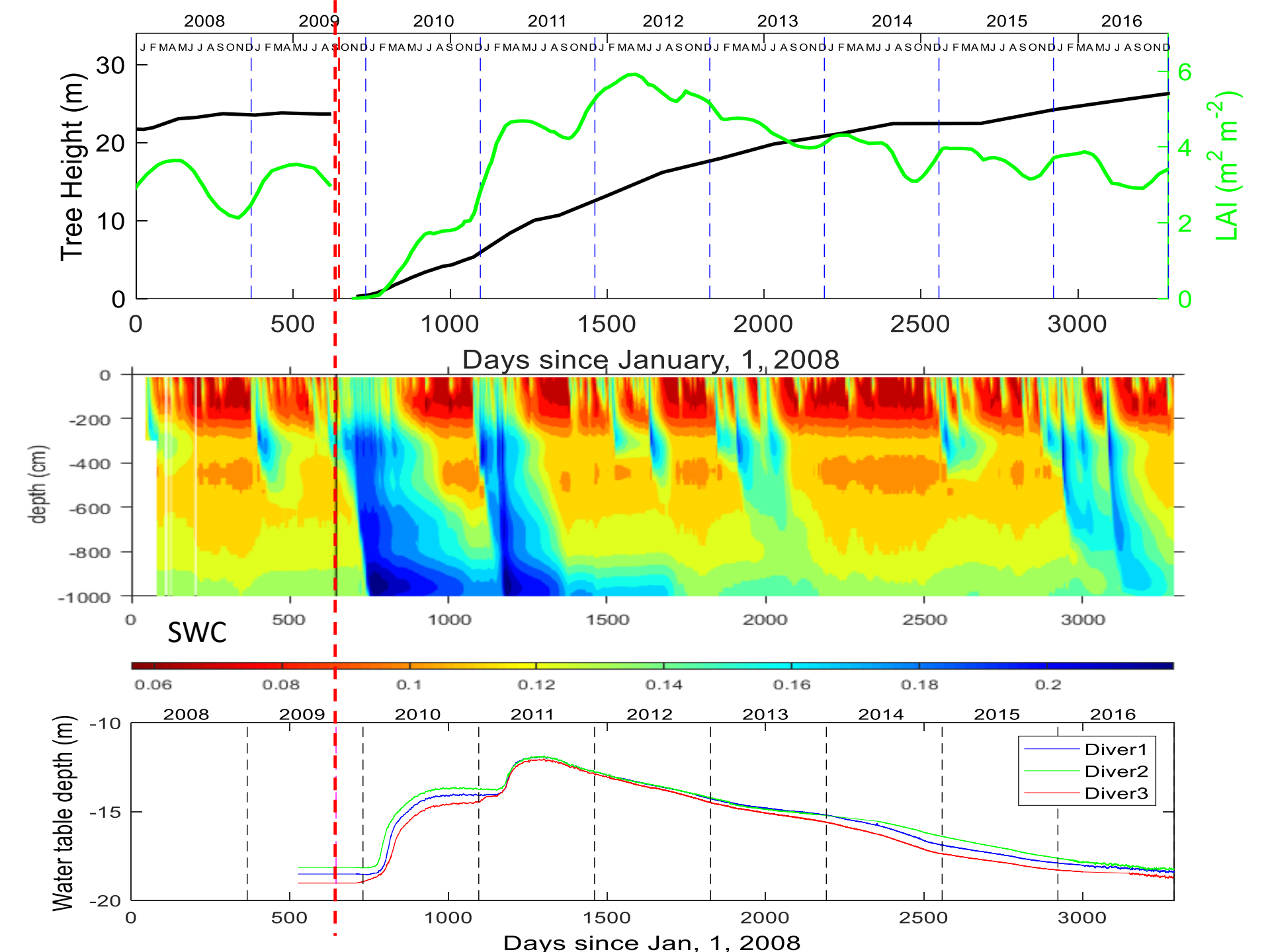
Deep soil water recharge after clearcuting, and use of stored water the following years



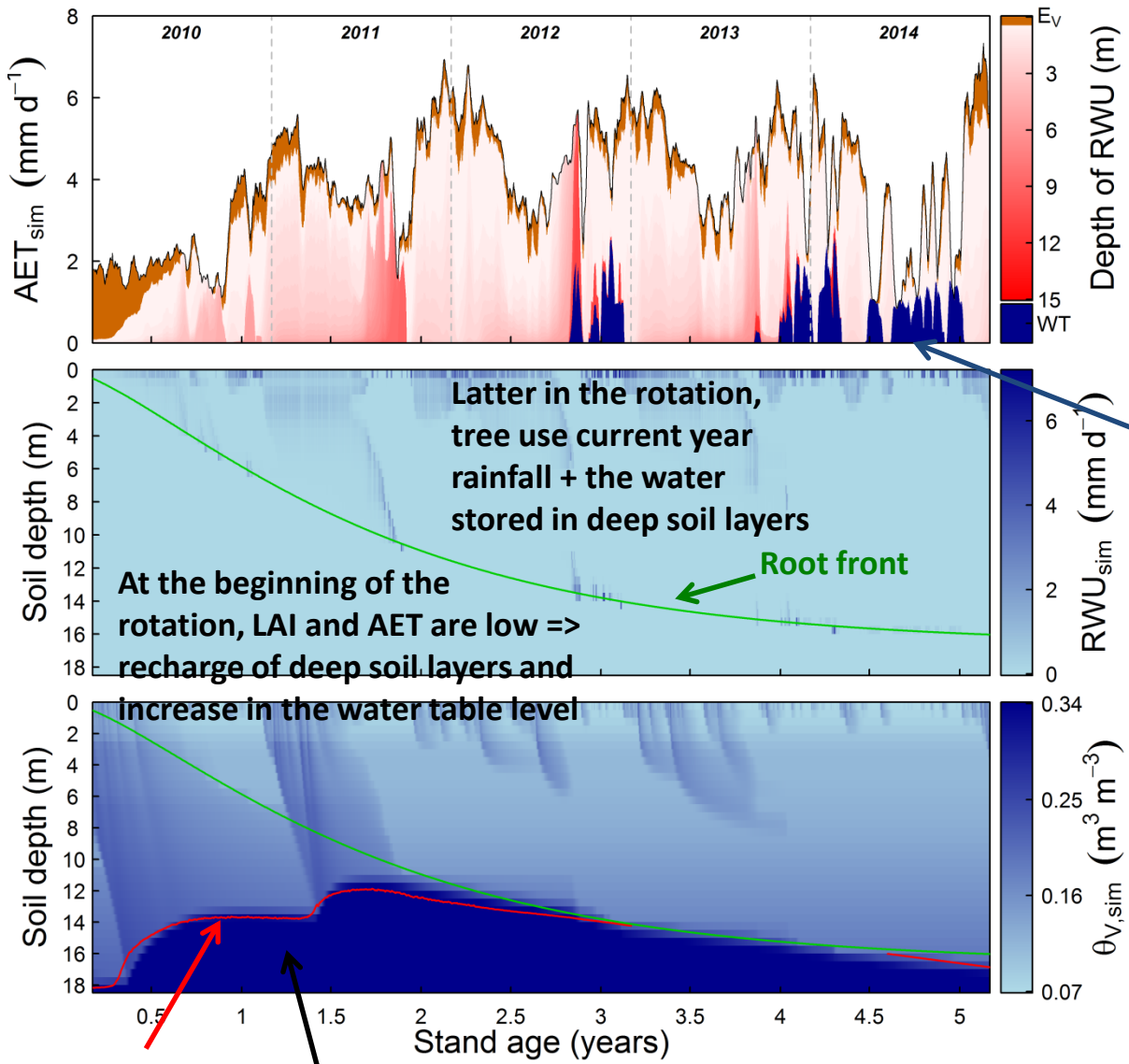


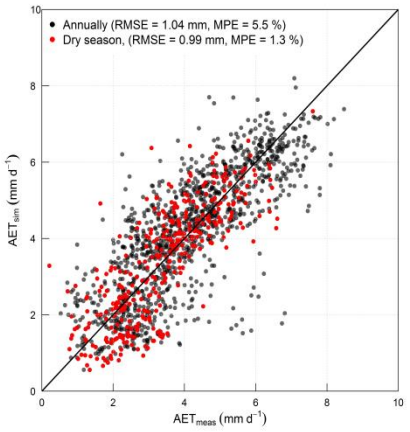





2008
2009
2010
2011
2012
2013
2014
2015
2016
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
Tree Height (m)
LAI (m2 m-2)
Days since January, 1, 2008
depth (cm)
SWC
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
Water table depth (m)
Diver1
Diver2
Diver3
Days since Jan, 1, 2008

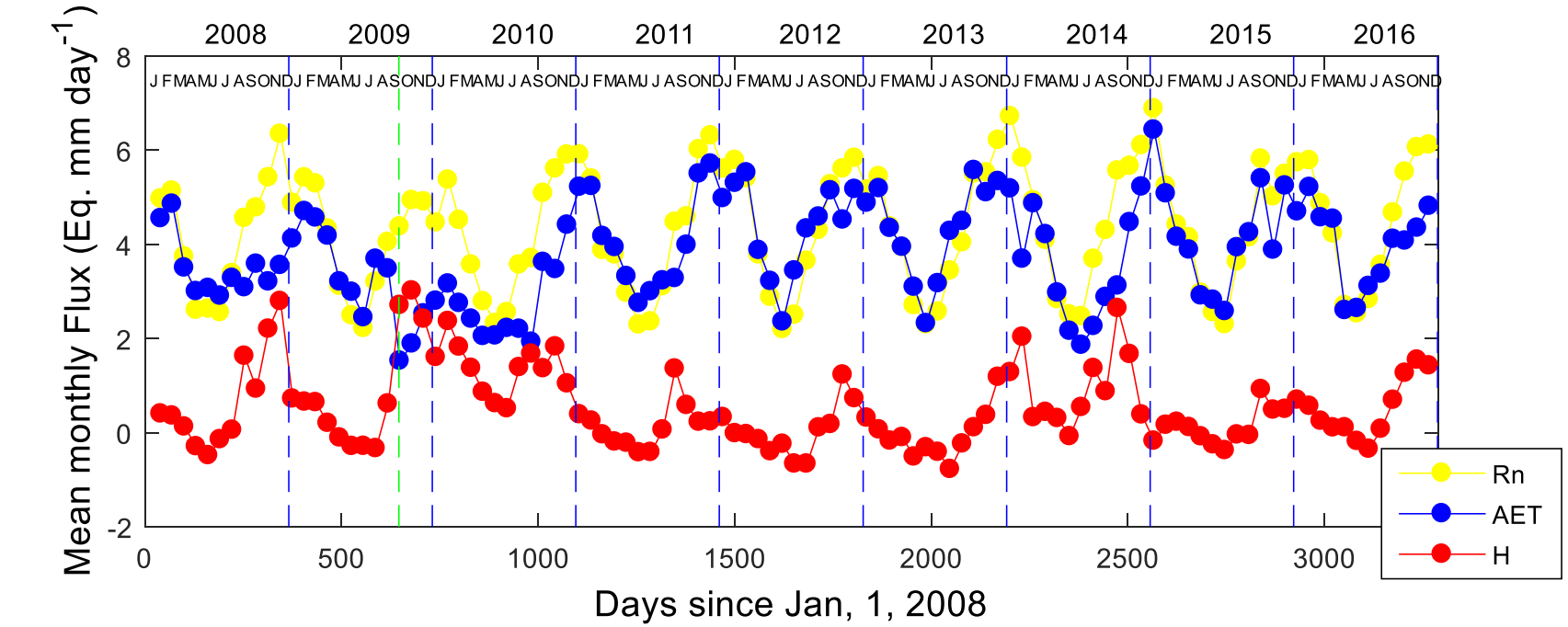
Depth of water uptake for the first 5 years of the second rotation: measurements and simulations (MAESPA model; Christina et al., Functional Ecology, 2017)

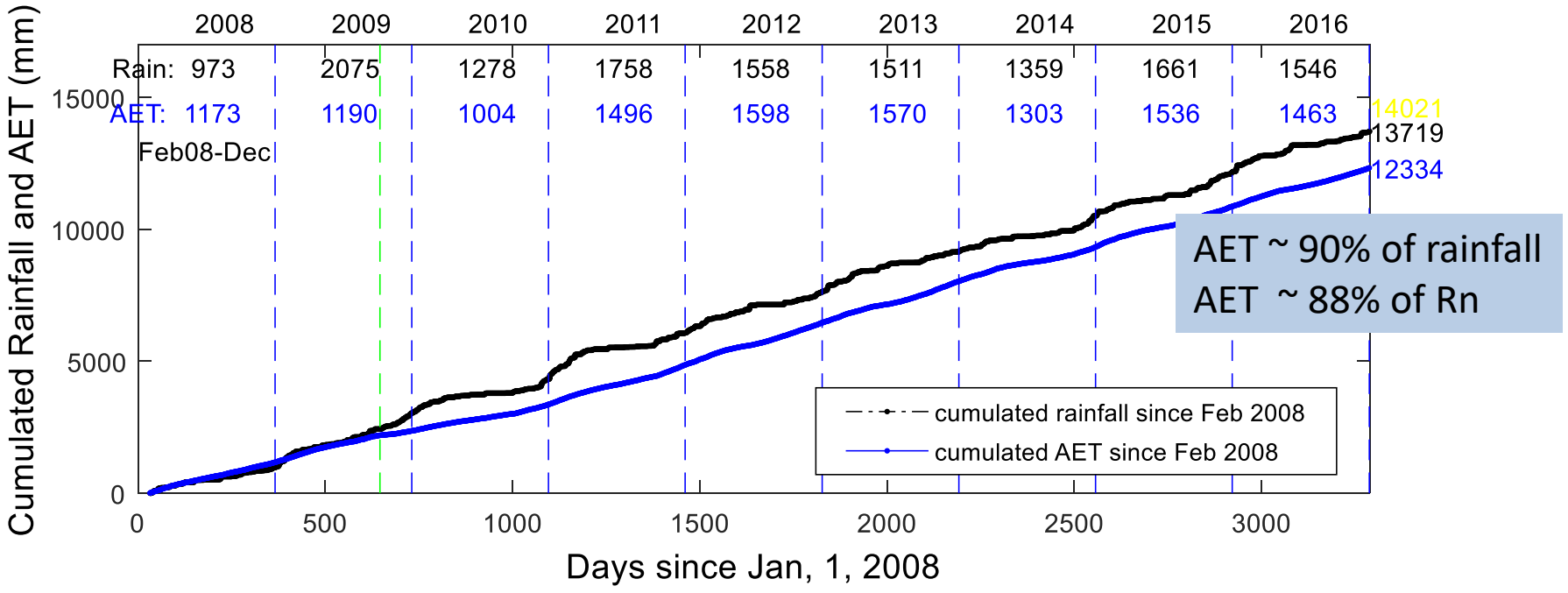


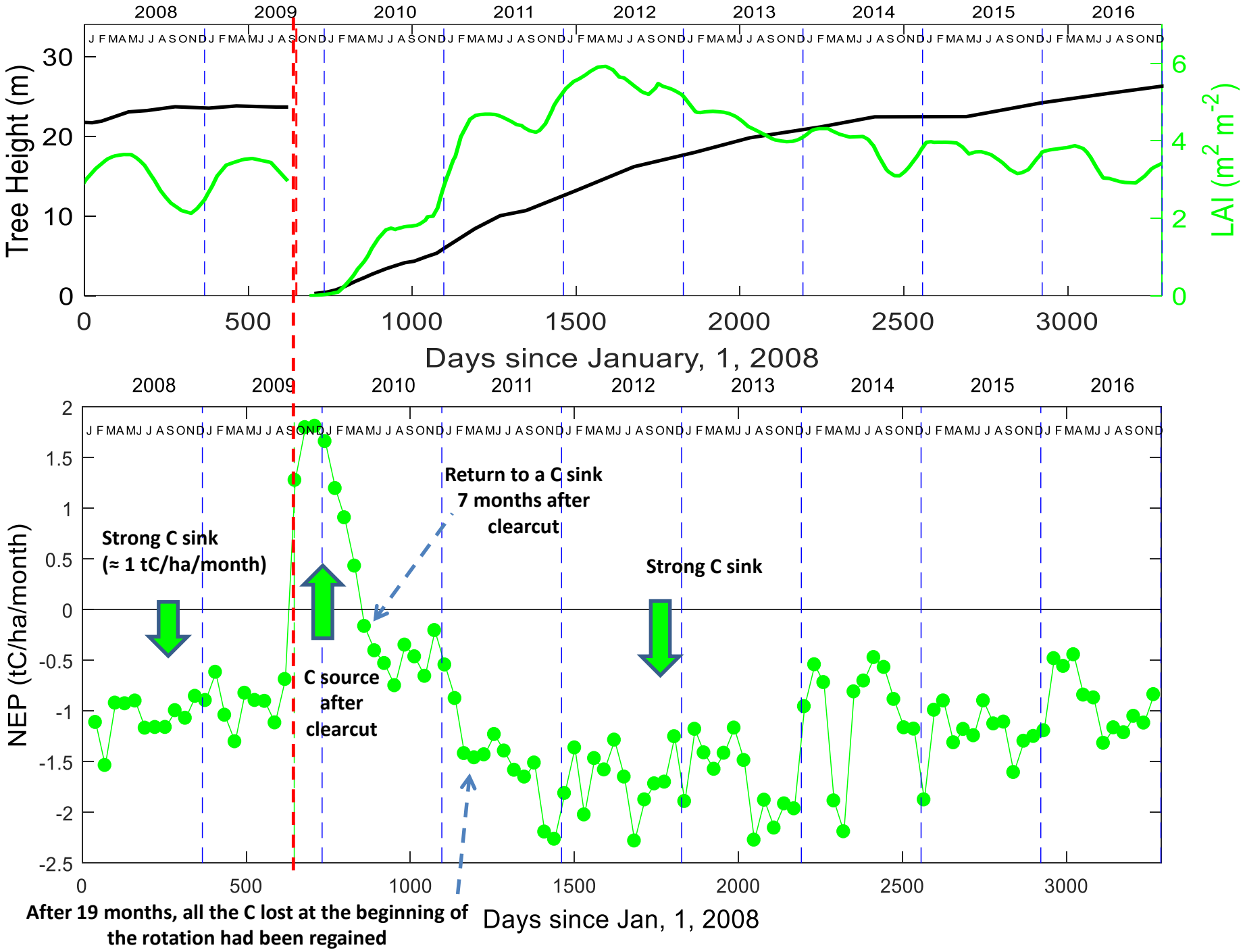


Ground water uptake are low, but are important to help trees to survive during severe drought

Importance of deep soil water to meet water requirments of the trees, sustain their fast growth and help them to cope with seasonal drought


2008 2009 2010 2011 2012 2013 2014 2015 2016
J FMAMJ J ASONDJ FMAMJ J ASONDJ FMAMJ J ASONDJ FMAMJ J ASONDJ FMAMJ J ASONDJ FMAMJ J ASONDJ FMAMJ J ASONDJ FMAMJ J ASONDJ FMAMJ J ASOND
Mean monthly Flux (Eq. mm day-1)
8
6
4
2
0
-2
0
500
1000
1500
2000
2500
3000
Days since Jan, 1, 2008
Rn
AET
H


2008 2009 2010 2011 2012 2013 2014 2015 2016
Rain: 973 2075 1278 1758 1558 1511 1359 1661 1546
AET: 1173 1190 1004 1496 1598 1570 1303 1536 1463
Feb08-Dec
14021
13719
12334
Cumulated Rainfall and AET (mm)
15000
10000
5000
0
0
500
1000
1500
2000
2500
3000
Days since Jan, 1, 2008
cumulated rainfall since Feb 2008
cumulated AET since Feb 2008
AET ~ 90% of rainfall
AET ~ 88% of Rn


2008
2009
2010
2011
2012
2013
2014
2015
2016
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
Tree Height (m)
LAI (m2 m-2)
Days since January, 1, 2008
NEP (tC/ha/month)
Strong C sink
(≈ 1 tC/ha/month)
Return to a C sink
7 months after
clearcut
C source
after
clearcut
Strong C sink
After 19 months, all the C lost at the beginning of
the rotation had been regained
Days since Jan, 1, 2008

CONCLUSIONS

- High AET at this site (1380 mm yr^{-1}), similar to the AET reported for tropical humid forests (e.g. 1370 mm yr^{-1} for Amazonia-wide evapotranspiration; Fisher et al., 2009; or 1460 mm yr^{-1} for rubber tree plantations growing on deep soils in Cambodia; Gambielluca et al., 2016), but higher than nearby native vegetation (ex: cerrado), crops (sugar-cane, …), and grasslands

- This high AET (and wood production) is not surprising since *Eucalyptus grandis* is considered as a « long-lived emergent rainforest pionner tree species » (Tng et al., 2012; 2013), and the plantations are fertilised (strong positive effect of fertilisation on AET => see Christina et al., FEM 2018)

- The high AET (and productivity) at this site was allowed by the deep water storage (deep soils) and the capacity of tree to use this water from deep soil layers.

- The productivity at this site could not be increased through increased water use, since any further increase in AET is limited by both rainfall and energy availability => the only way to increase productivity is through increased WUE

- Other works on factors driving the NEP are ongoing

Thanks!

High…

And…

Deep!