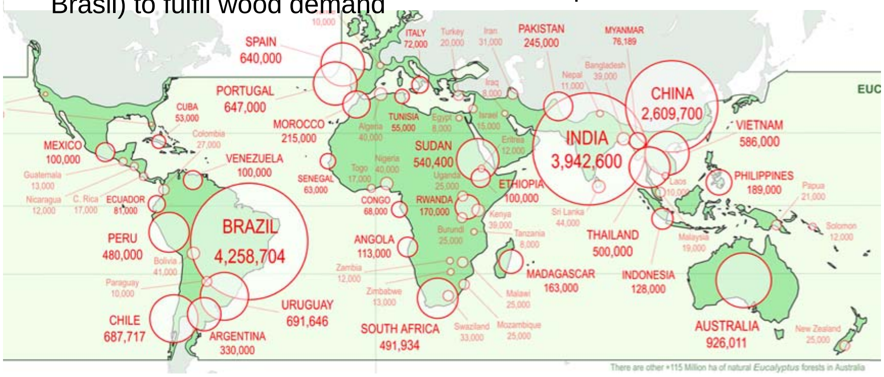
Do changes in carbon allocation account for the growth response to fertilization in tropical Eucalyptus plantations?

Daniel Epron, Yann Nouvellon, Jean-Paul Laclau, Antoine Kinana, Jean-Claude Mazoumbou, Julio Raposo de Almeida, Raphael Romao, Laurent Saint-André, Philippe Deleporte, Jose Leonardo de Moraes Gonçalves, Irae Guerrini, Jean Pierre Bouillet

AGU Fall meeting 13-17 December 2010

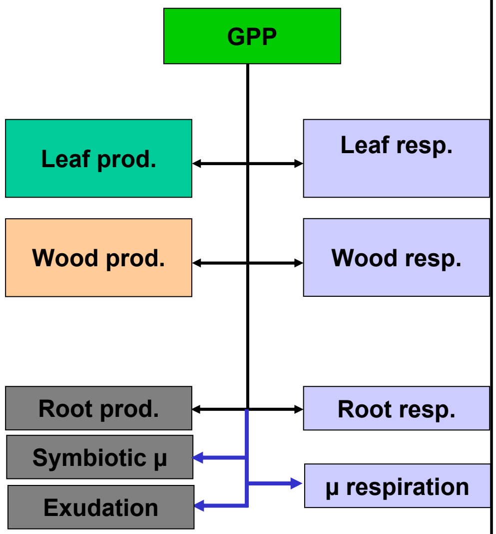
Introduction

- ➔ Eucalypts are among the most widely planted species in the tropics (20 millions ha)
- ➔ Rapid expansion of eucalypt plantations (300 000 ha/year in Brasil) to fulfil wood demand
- ➔ This expansion concerns mainly marginal lands
- ➔ Cost of fertilizer is increasing
- ➔ Potassium is limited in most tropical weathered soils



Introduction

- ➔ K fertilization is known to stimulate wood production in eucalypt plantations
- ➔ Little is known about the mechanism
  - ✓ Stimulation of GPP ?
  - ✓ Change in C allocation ?
- ➔ In nutrient-limited environment
  - ✓ The amount of carbon allocated belowground is higher **=> efficient resource acquisition**
  - ✓ The leaf life span is longer **=> efficient resource conservation**
  - ✓ Na can partly replace K **=> efficient resource substitution**

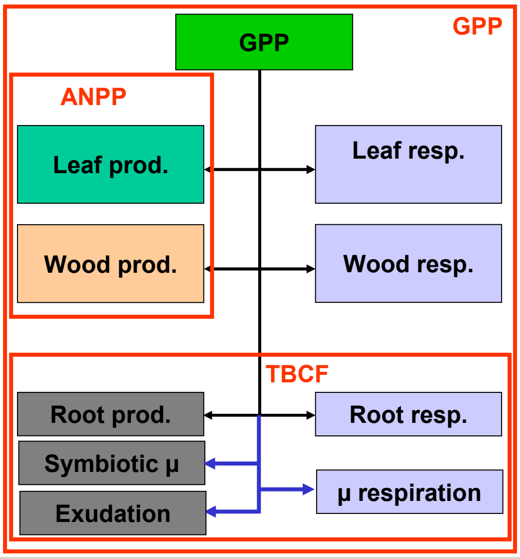


Nancy-Université INRA cirad

(3)

Objective

- ➔ The tested hypotheses were that
  - ✓ Leaf life span decreases in response to K fertilisation
  - ✓ Belowground C allocation decreases in response to K addition
  - ✓ Na can be a substitute to K for Eucalyptus
- ➔ Partitioning ANPP between wood and leaf production
- ➔ Estimating TBCF from soil respiration and litterfall
- ➔ Estimating and partitioning GPP

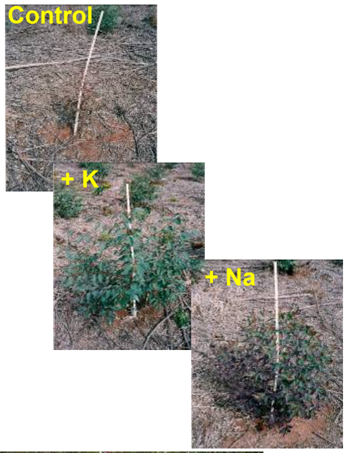


Nancy-Université INRA cirad

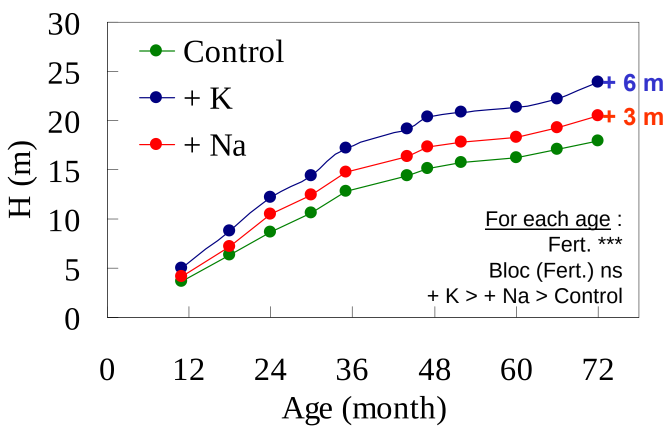
(4)

Experimental design

- ➔ Seedlings of *E. grandis* planted in 2004 on site afforested since more than 60 years
  - ✓ Control (standard fertilisation except K)
  - ✓ + K (4.5 kmol ha^{-1} of KCl fertilizer applied)
  - ✓ + Na (NaCl was applied instead of KCl)
- ➔ Tree census (height and dbh) every six months
- ➔ Tree biomass on 8 trees per treatment each year up to year 6 (2010) => allometric relations
- ➔ Leaf litter fall in litter trap



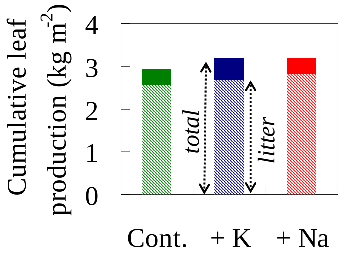
Above ground net primary production

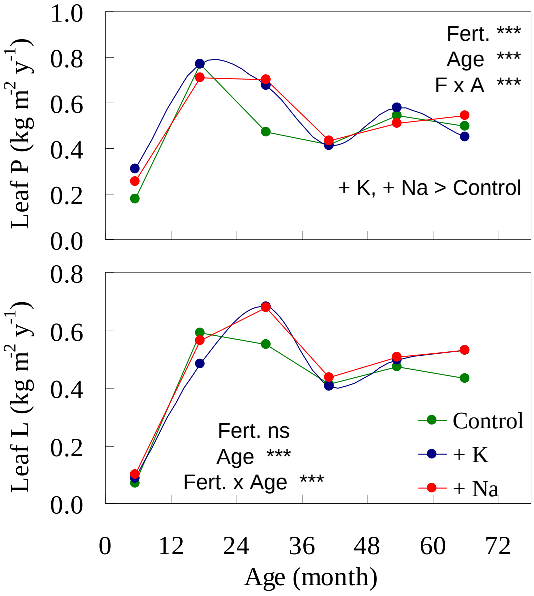


- ➔ Height growth was stimulated by both Na and K fertilization at all ages
- ➔ The effect of K was higher than the effect of Na

Above ground net primary production

- ➔ Leaf production was slightly stimulated by both K and Na fertilization
- ➔ There was no difference in leaf litter fall





- ➔ Higher standing leaf biomass in the + K treatment

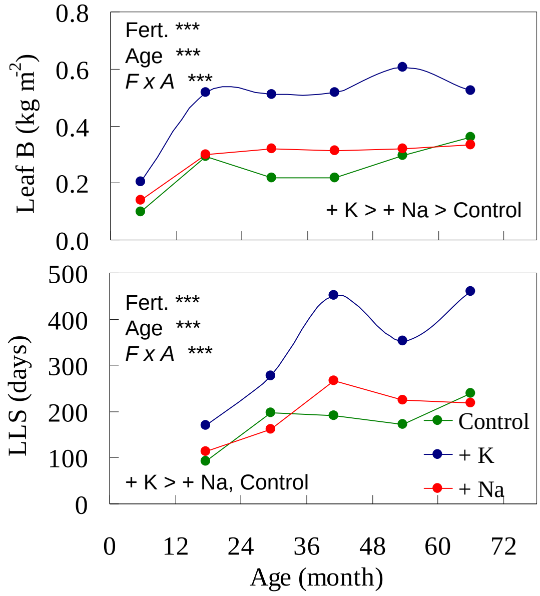
Nancy-Université INRA cirad (7)

Above ground net primary production

- ➔ Therefore, leaf biomass of fertilized trees was higher than in control
- ➔ The effect of K was much higher than the effect of Na
- ➔ Increase in leaf life span in response to K fertilization but not to Na fertilization

⇒ **K increases leaf life span with a strong consequence for leaf biomass and leaf area index**

⇒ **Higher GPP**

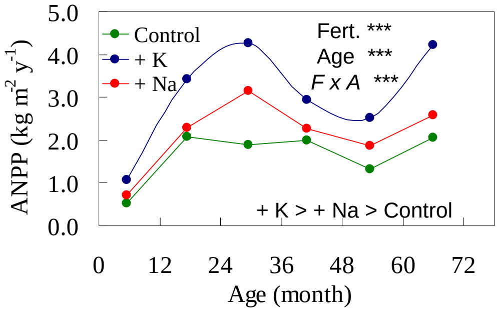


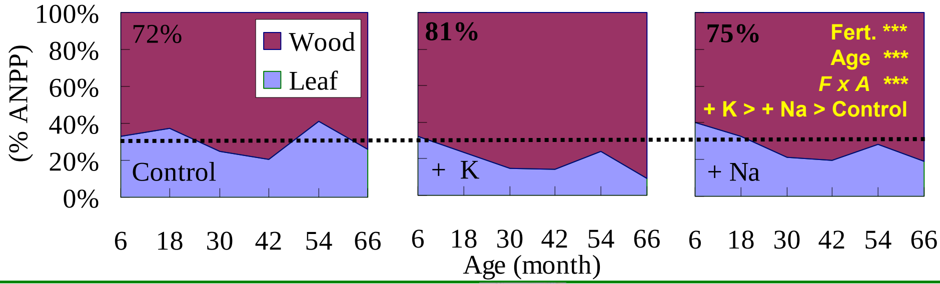
Nancy-Université INRA cirad (8)

Above ground net primary production

➔ The increase in wood production in response to K and Na fertilisation is both due to

- ✓ an increase in ANPP
- ✓ a change in allocation increasing partitioning to wood growth instead of leaf production





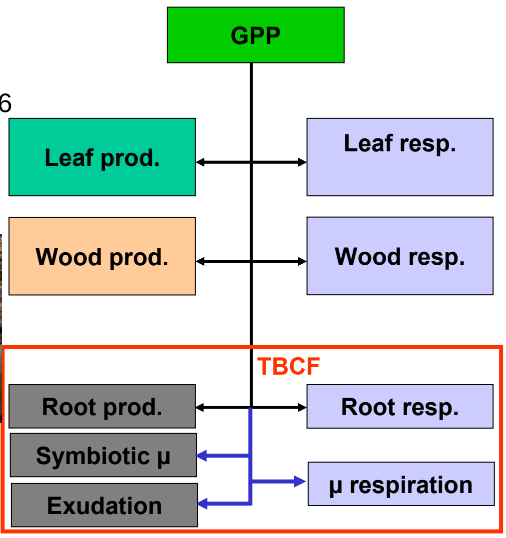
Nancy-Université Université Henri Poincaré INRA cirad C.R.D.P.I ESALQ

Total belowground carbon flow

➔ Coarse root biomass was measured at age 5 and 6

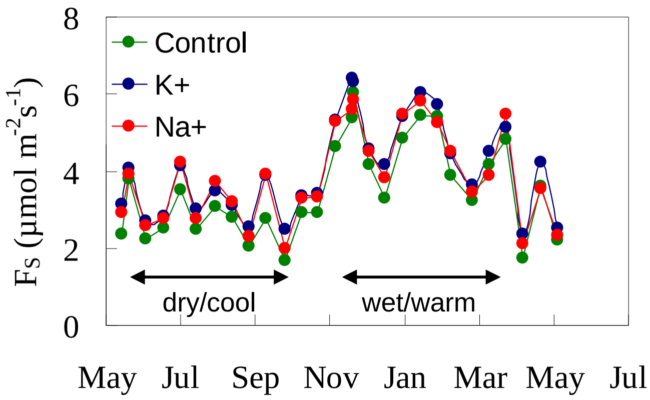
➔ Litter amount on the forest floor was also measured at age 5 and 6

➔ Soil CO_2 efflux was measured every two weeks during one year between age 5 and 6



Nancy-Université Université Henri Poincaré INRA cirad C.R.D.P.I ESALQ

Total belowground carbon flow



Annual cumulative F_S : Control 1.24 ± 0.17[a] kg_C m^{-2}

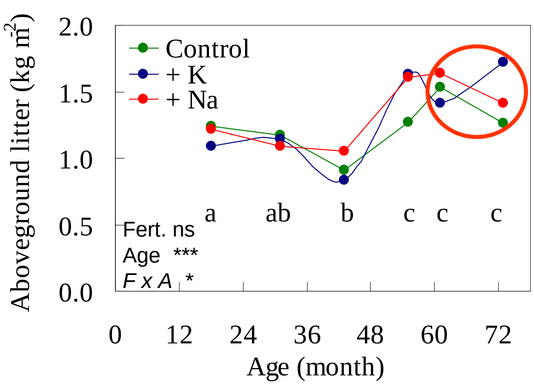
+ K 1.45 ± 0.23[b]

+ Na 1.39 ± 0.22[b]

Fert. **
Bloc (Fert.) *
+ K , + Na > Control

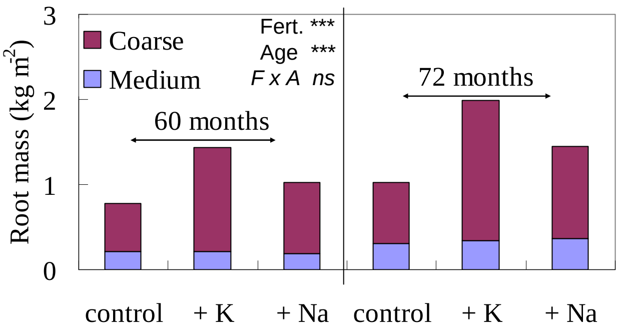
- ➔ Seasonal fluctuations in soil CO_2 efflux with greater values during the wet/warm season than during the dry/cold season
- ➔ Annual soil respiration is higher in fertilized plots than in the control plots
- ➔ no difference between K and Na fertilization

Total belowground carbon flow



- ➔ The amount of litter aboveground first decreased during 3 years and increased again thereafter
- ➔ There was no difference among the different fertilization treatment
- ➔ There was no change between year 5 and 6

Total belowground carbon flow



- ➔ The total root biomass is higher in + K plots and lower in control plots
- ➔ The biomass of medium and coarse roots increased between age 5 and 6.

Total belowground carbon flow

$$TBCF = \Delta_{root} + R_{root} + P_{beglitter}$$

heterotrophic respiration

$$R_{root} = R_{soil} - \left(P_{beglitter} + P_{abglitter} - \Delta_{abglitter} - \Delta_{beglitter} - \Delta_{SOM} - E\right)$$

$$TBCF = \Delta_{root} + R_{soil} - P_{abglitter} + \underbrace{\Delta_{abglitter} + \Delta_{beglitter} + \Delta_{SOM} + E}_{\approx 0}$$

- ➔ We checked
  - ✓ Constant aboveground litter on the forest floor at this age
- ➔ We assumed
  - ✓ Constant fine root biomass and necromass at this age
  - ✓ No change in SOM after more than 60 years of afforestation with eucalypts
  - ✓ No exportation of carbon (CH_4, leaching or erosion)

Total belowground carbon flow

$$TBCF = \Delta_{root} + R_{root} + P_{beglitter}$$

heterotrophic respiration

$$R_{root} = R_{soil} - \left(P_{beglitter} + P_{abglitter} - \Delta_{abglitter} - \Delta_{beglitter} - \Delta_{SOM} - E\right)$$

$$TBCF = \Delta_{root} + R_{soil} - P_{abglitter} + \underbrace{\Delta_{abglitter} + \Delta_{beglitter} + \Delta_{SOM} + E}_{\approx 0}$$

($kg_C\ m^{-2}\ y^{-1}$)	TBCF	FS	L	⊿root
Control	1.13 ± 0.18[a]	1.24 ± 0.17[a]	0.23 ± 0.02[a]	0.12 ± 0.07[a]
+ K	1.48 ± 0.25[b]	1.45 ± 0.23[b]	0.23 ± 0.01[a]	0.26 ± 0.09[b]
+ Na	1.36 ± 0.23[b]	1.39 ± 0.22[b]	0.23 ± 0.06[a]	0.20 ± 0.04[c]

➔ A higher amount of carbon is allocated belowground in the fertilized plots

➔ There was not significant difference between K and Na fertilization

➔ Differences in TBCF are less than differences in ANPP

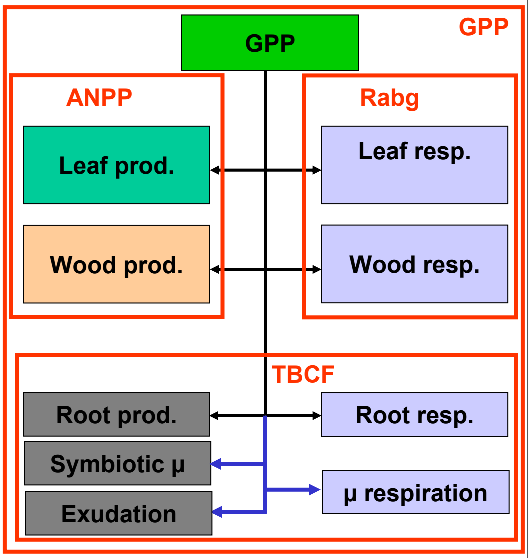
GPP partitioning

➔ we assumed similar and constant CUE (0.48) among treatment to estimate above ground respiration from ANPP

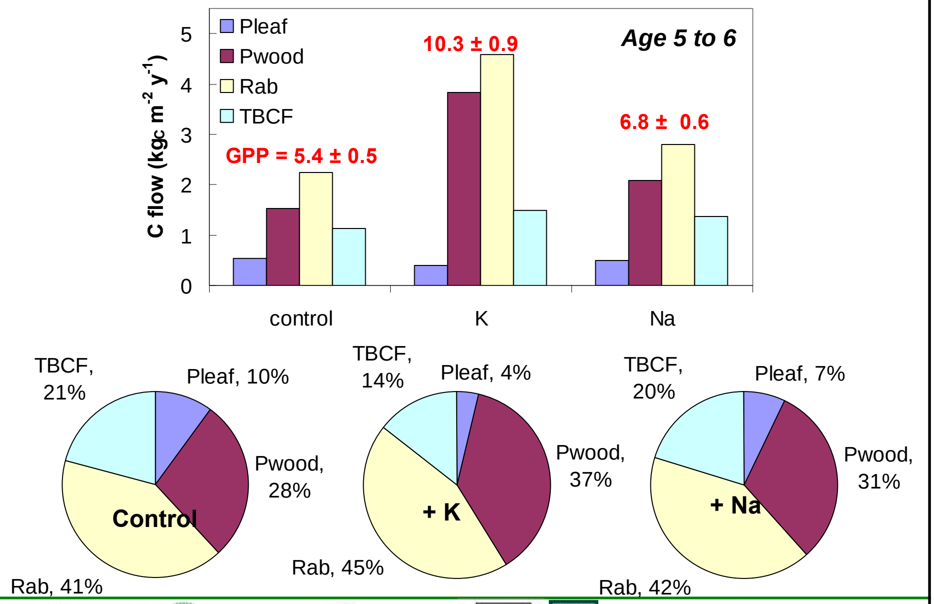
Ryan et al. 1996 Tree Physiol.

Giardina et al. 2003 GCB

➔ GPP = ANPP + Rabg +TBCF



Carbon allocation



Nancy-Université INRA cirad C.R.D.P.I ESALQ

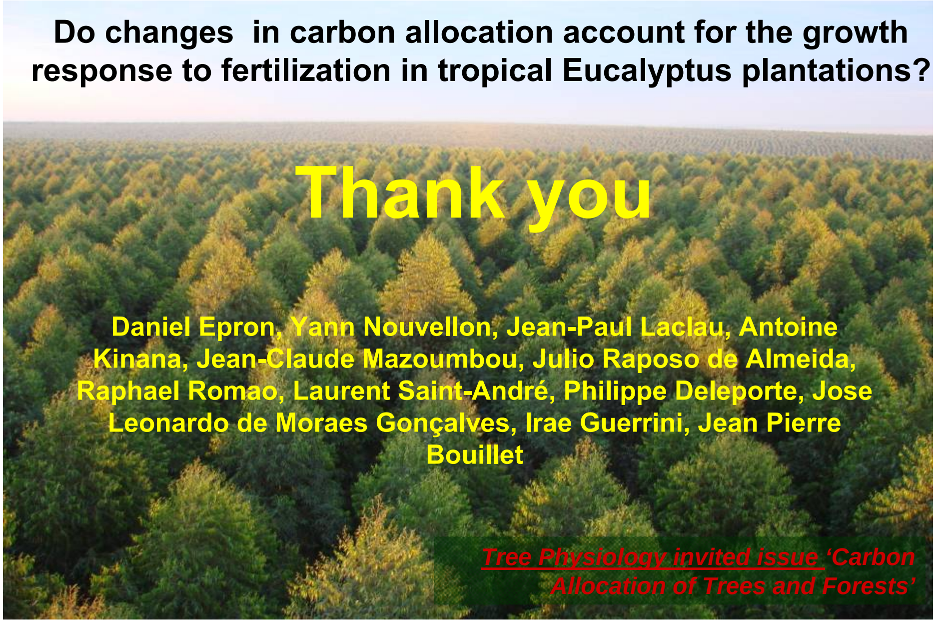
(17)

Conclusions

- ➔ GPP was strongly enhanced by K fertilisation while Na has a much smaller effect
- ➔ K fertilization:
  - ✓ Higher GPP and lower C allocation belowground lead to an enhanced ANPP
  - ✓ A higher leaf life span account for a lower allocation to leaf growth
  - ✓ A higher ANPP and a lower in C allocation to leaf growth account for an enhanced wood production
  - ✓ **Is there an effect on stomatal conductance? What is the water cost of the increase in productivity?**
- ➔ Na fertilization
  - ✓ Stimulation of GPP, ANPP and wood production
  - ✓ But Na cannot fully substitute for K.
  - ✓ This is especially the case for leaf life span.

Nancy-Université INRA cirad C.R.D.P.I ESALQ

(18)


Do changes in carbon allocation account for the growth response to fertilization in tropical Eucalyptus plantations?
Thank you
Daniel Epron, Yann Nouvellon, Jean-Paul Laclau, Antoine Kinana, Jean-Claude Mazoumbou, Julio Raposo de Almeida, Raphael Romao, Laurent Saint-André, Philippe Deleporte, Jose Leonardo de Moraes Gonçalves, Irae Guerrini, Jean Pierre Bouillet
Tree Physiology invited issue 'Carbon Allocation of Trees and Forests'

(19)