

# CLIMATE CHANGE AND ITS IMPACTS ON FORESTRY ECOSYSTEMS

**ARISTIDES RIBEIRO**

**Departamento de Engenharia Agrícola – UFV**

**[ribeiro@ufv.br](mailto:ribeiro@ufv.br)**



# FORESTRY AREA IN BRAZIL

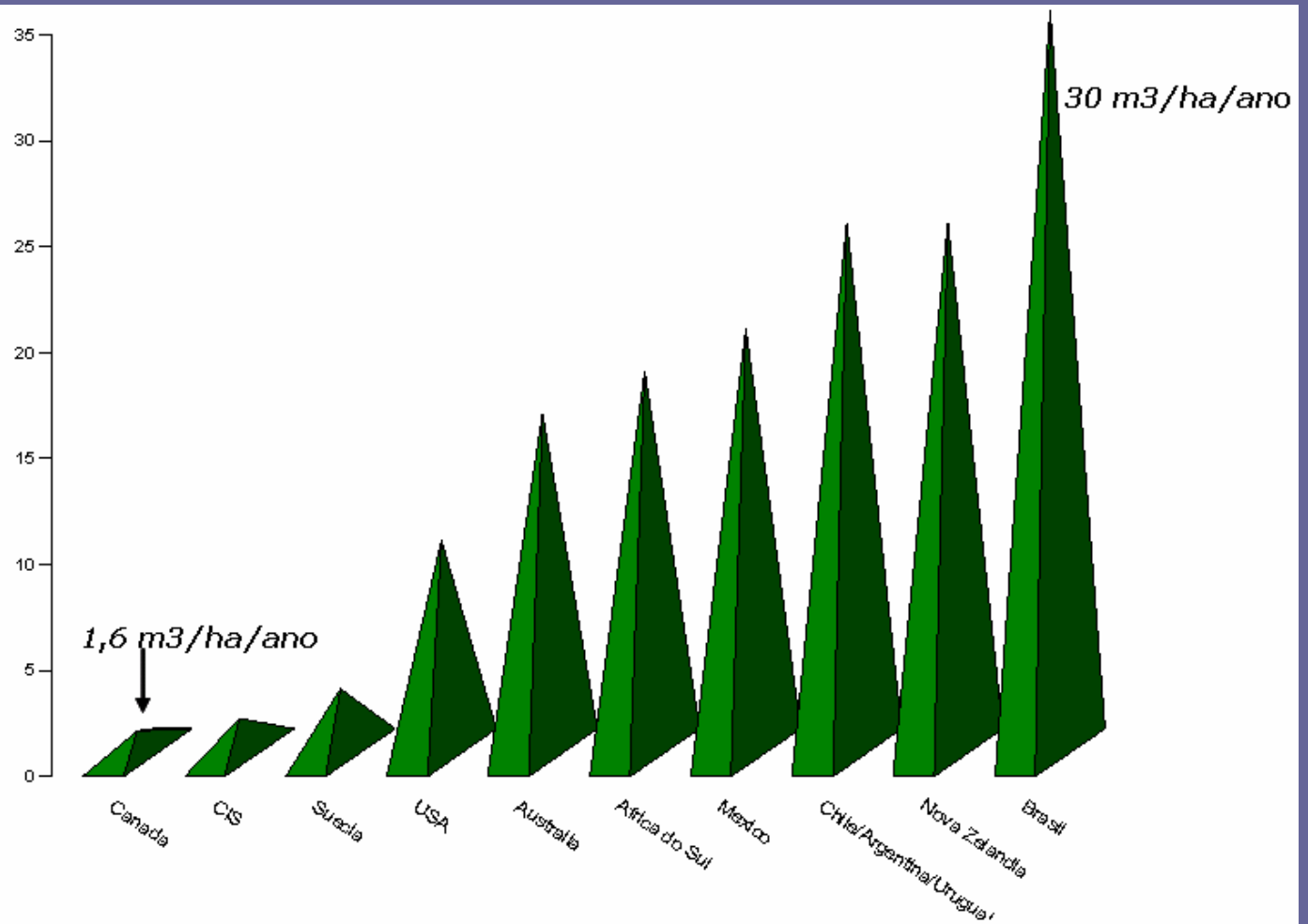
Area = 6.0 million ha



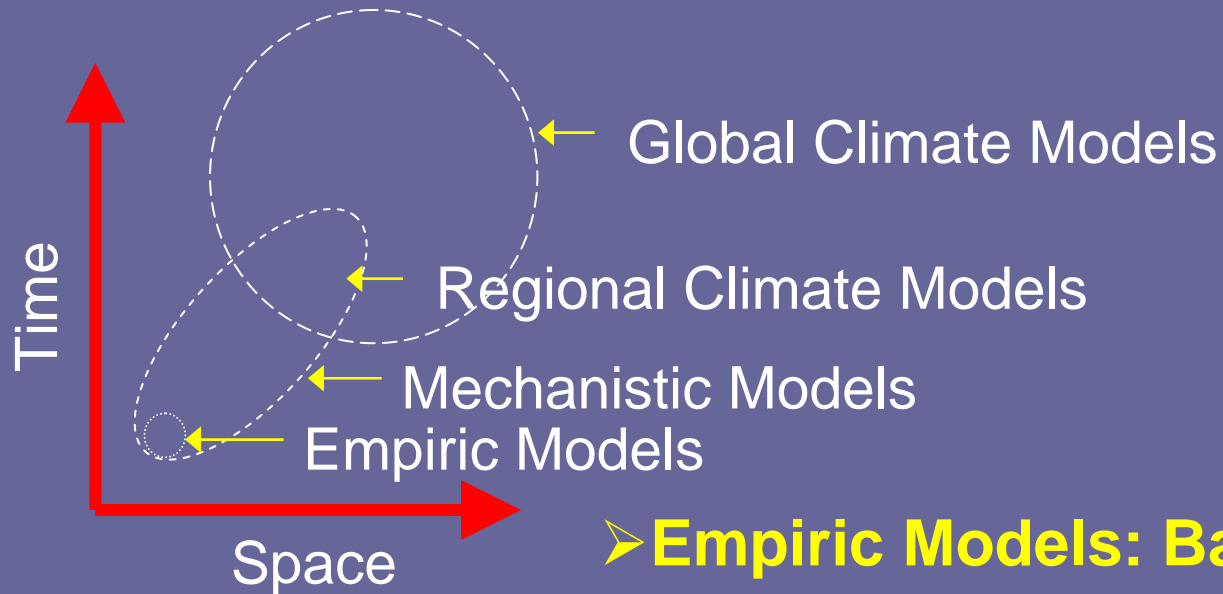
Eucalyptus  
3.8 million ha  
4.8 million ha  
end 2008

# WORLD FORESTRY COMPETITION

## IMA ( $\text{m}^3\text{ha}^{-1}\text{ano}^{-1}$ )



# MODELING AS A IMPORTANT TOOLS



➤ **Empiric Models: Based on variables correlation in a system, it is valid for specific environmental conditions.**

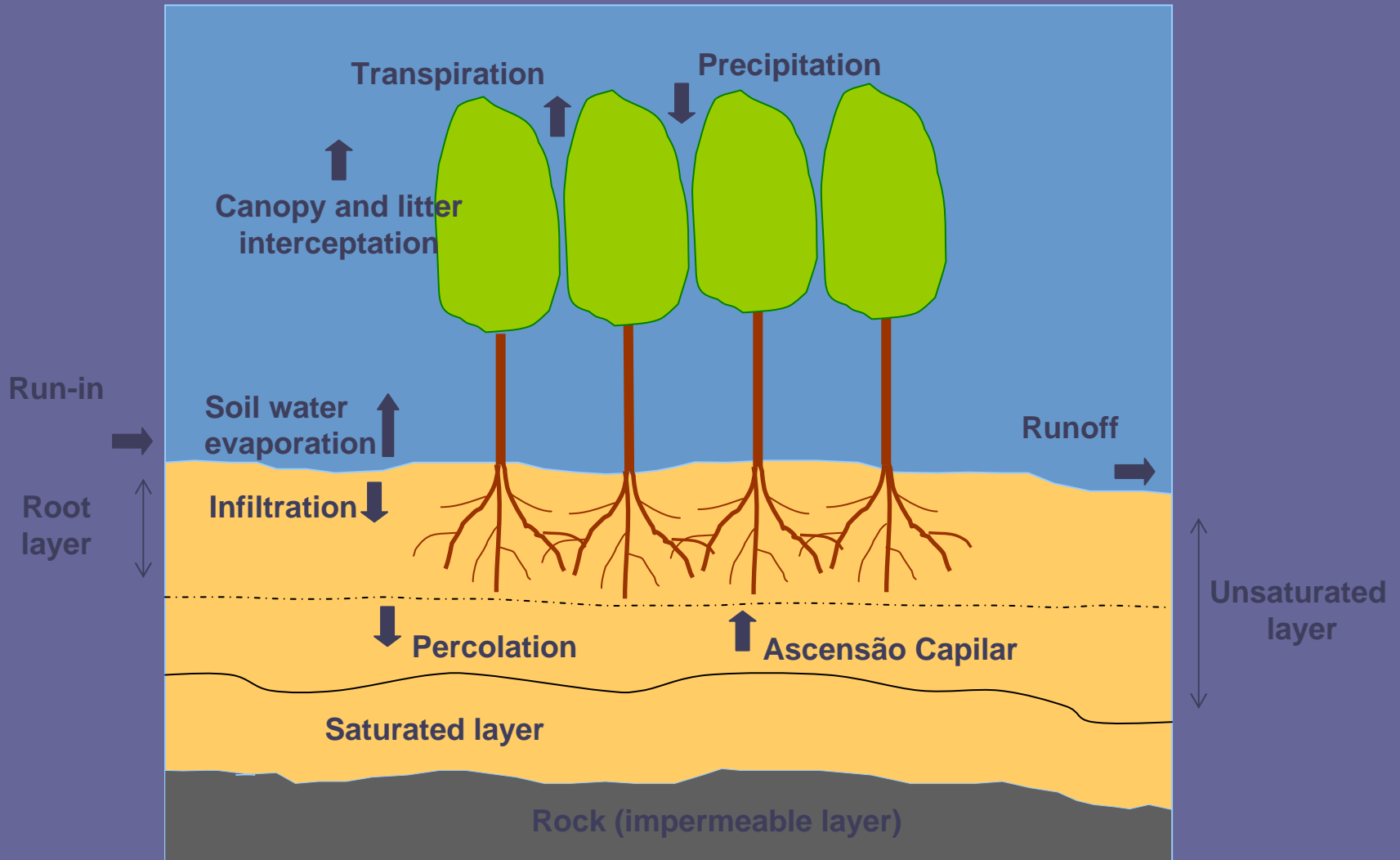
➤ **Mechanistic Models: Based on biophysics process that drive the exchanges in the**

➤ **soil-tree-atmosphere system.**



# WATER BALANCE COMPONENTS

$$ARM_i = ARM_{i-1} + P_i - T_i - Es_i - Id_i - Is_i + ESCe_i - ESCs_i - EXC_i + ASC_i$$



# CANOPY INTERCEPTION – RUTTER MODEL



Water Evaporation of Leaf Surface

Gross Rainfall

Idade	S (mm)	p	St (mm)	pt
1 ANO	0,50	0,91	0,113	0,024
2 ANOS	0,45	0,93	0,105	0,023

Water Evaporation of Trunk Surface

$$E = E_p \cdot C/S$$

$$E = E_{pt} \cdot C_t/S_t$$

Throughfall

Free Precipitation

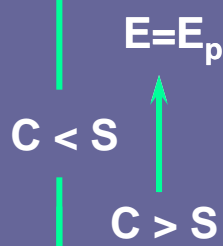
Stemflow

$$(1 - p - p_t) \cdot P$$

$$p \cdot P$$

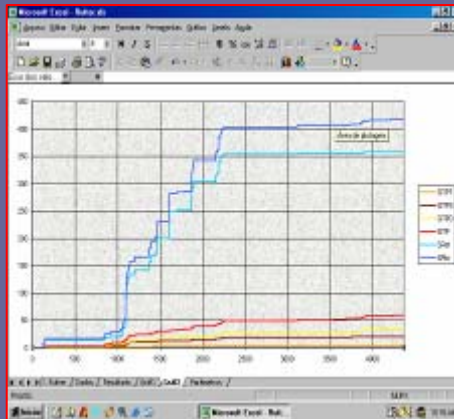
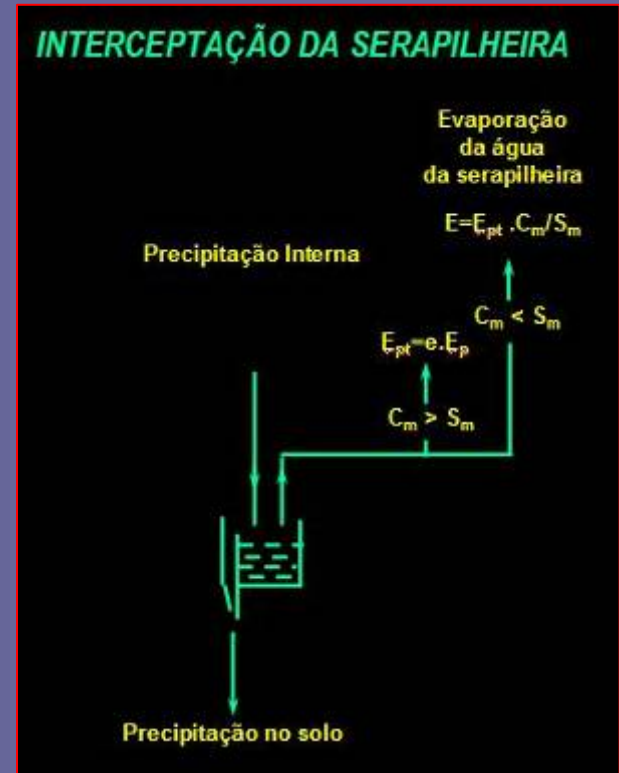
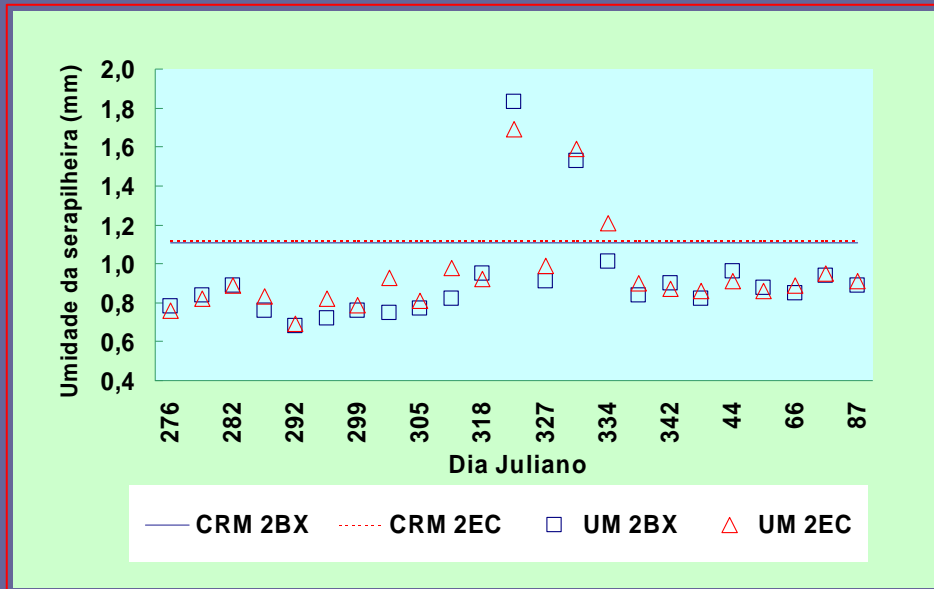
$$p_t \cdot P$$

$$E_{pt} = e \cdot E_p \cdot \frac{C_t < S_t}{C_t > S_t}$$



Internal precipitation Trunk flow

# RAINFALL LITTER INTERCEPTION MODELING



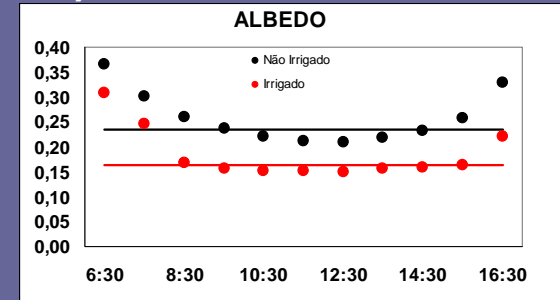
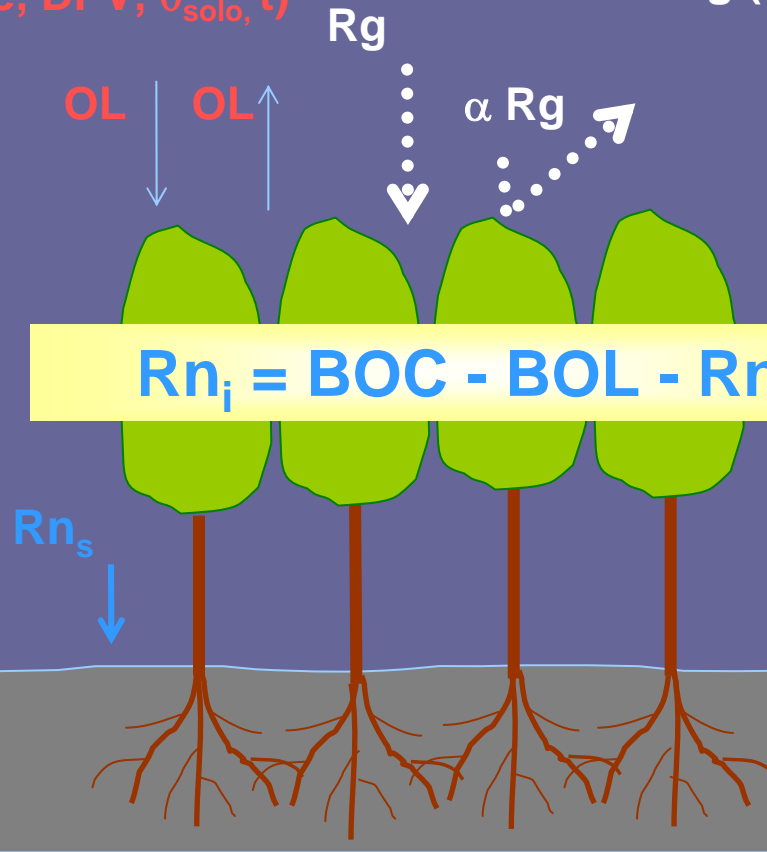


# NET RADIATION ( $Rn_i$ )

## LE, H (dossel, air and soil) e Biosynthesis.

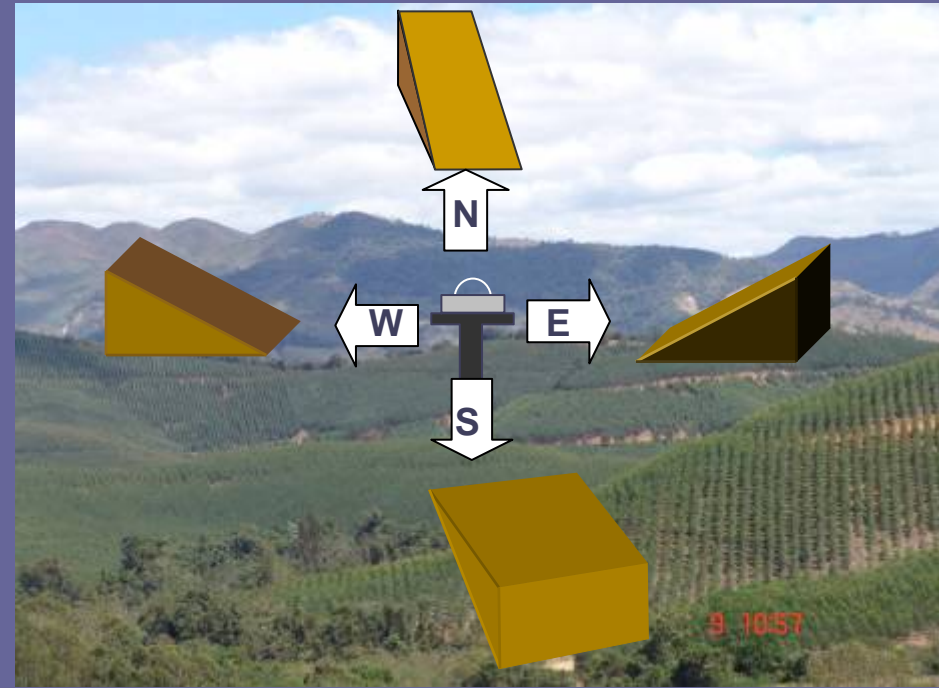
$BOL \Leftrightarrow f$  (Nebulosidade, DPV,  $\theta_{solo}$ , t)

$BOC = Rg (1 - \alpha)$





# ENERGY DISTRIBUTE INCLINATION AND EXPOSITION FACE OF THE HILLSIDE

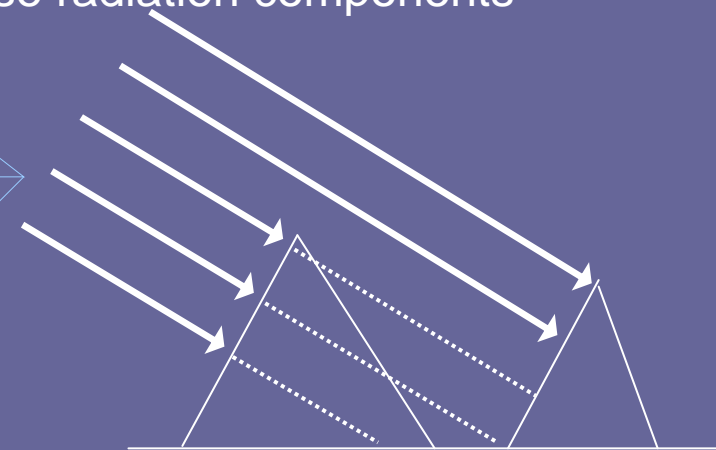


Fluxo Radiante

Área 2

Área 1

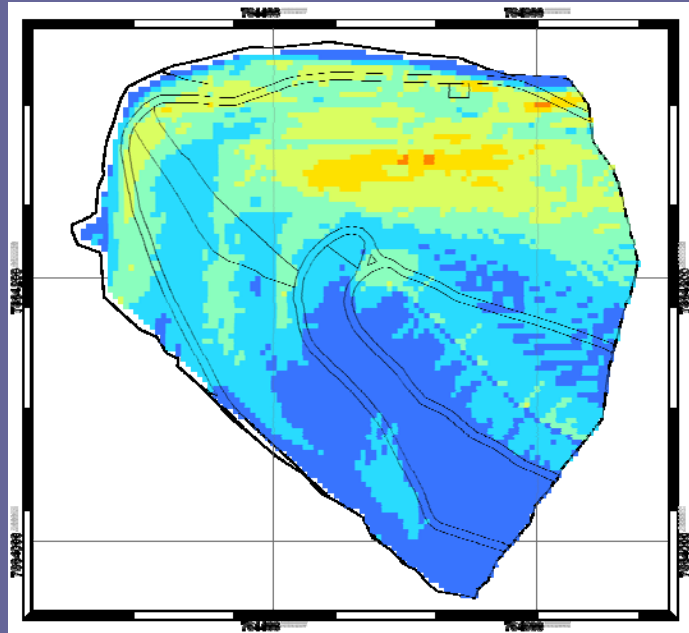
direct and diffuse radiation components



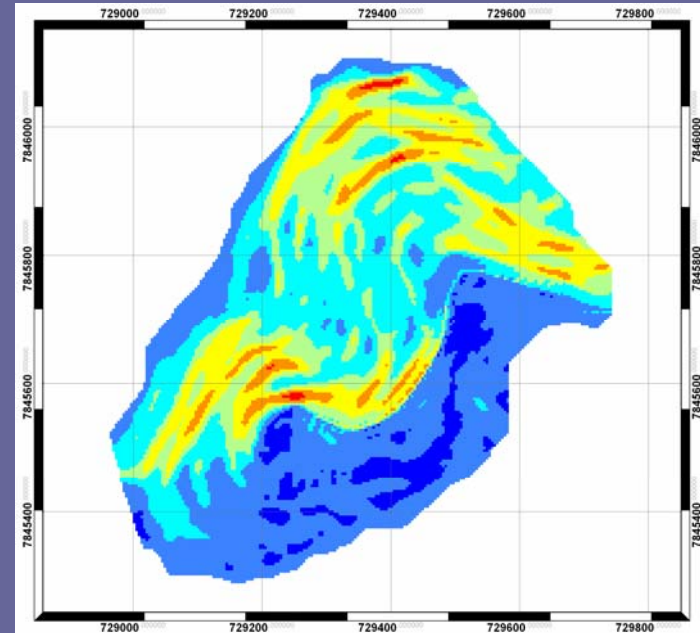
SHADE

# Short Waves Balance

Milagres



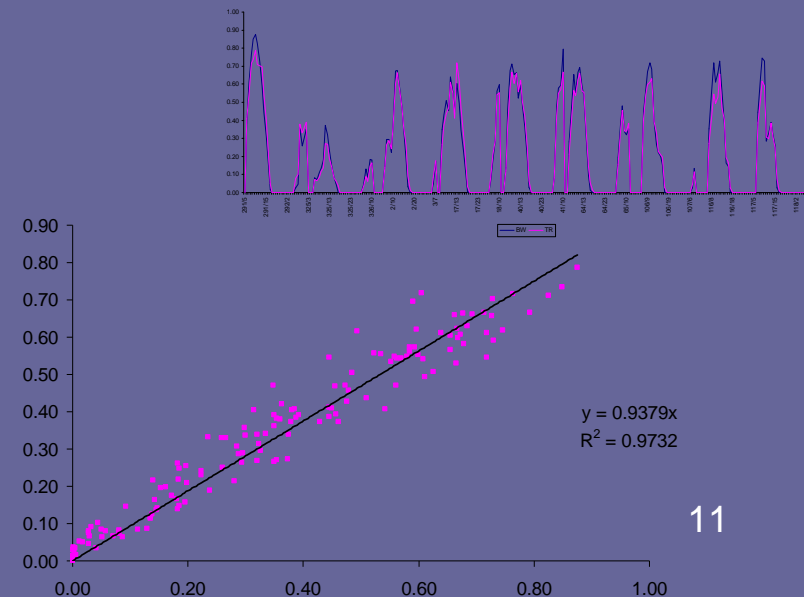
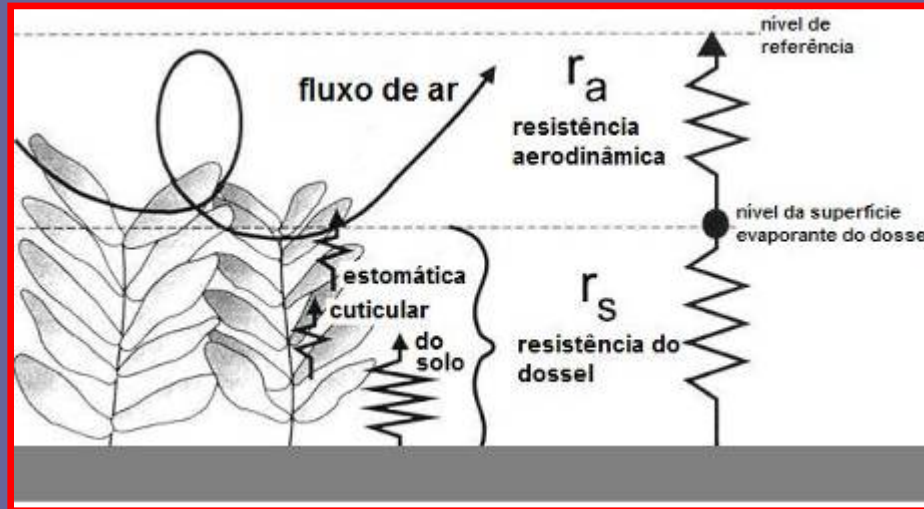
Vai e Volta



ANUAL AVERAGE 2005 ( $\text{MJ m}^{-2} \text{dia}^{-1}$ )

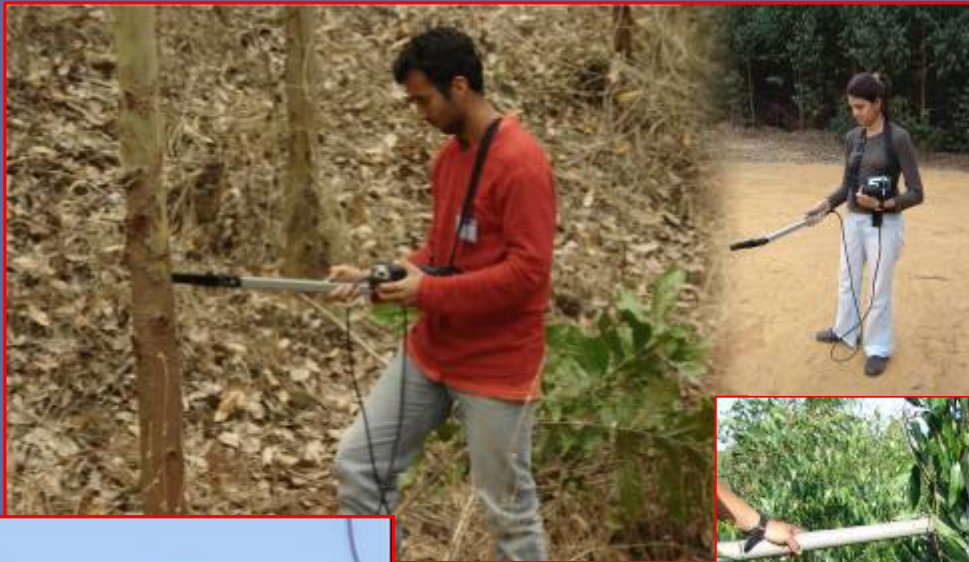


# MODELING OF AERODYNAMIC AND SUPERFICIAL CONTROL OF EVAPOTRANSPIRATION





# ECOPHYSIOLOGICAL MEASUREMENTS



# EXTRACTION ROOT CAPACITY VARIATION (MULTILAYER APPROACH)

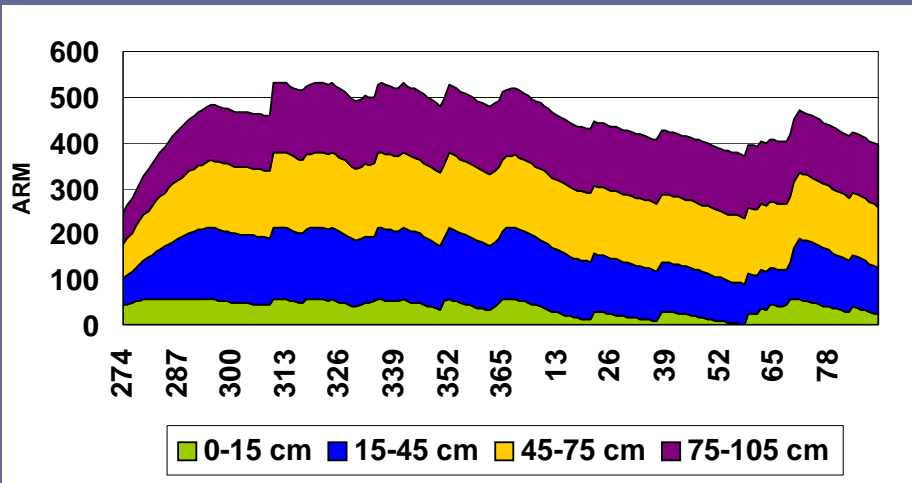
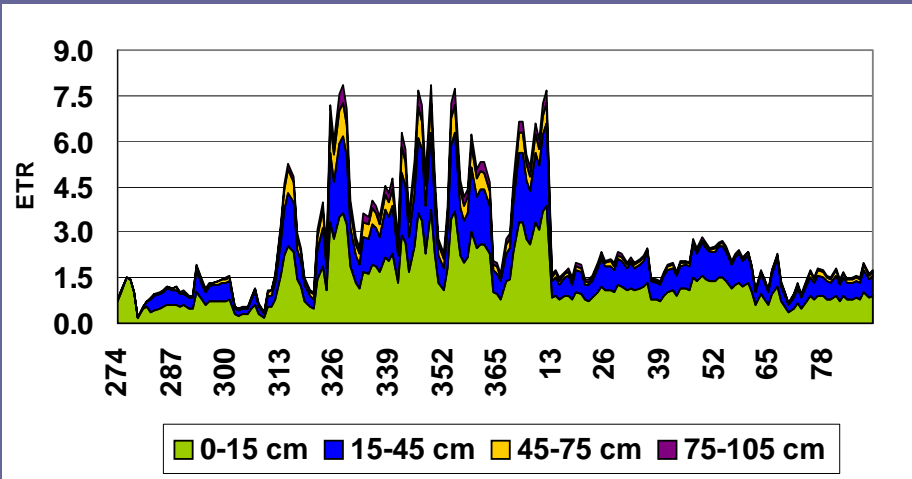
RAÍZES GROSSAS



RAÍZES MÉDIA



RAÍZES FINA



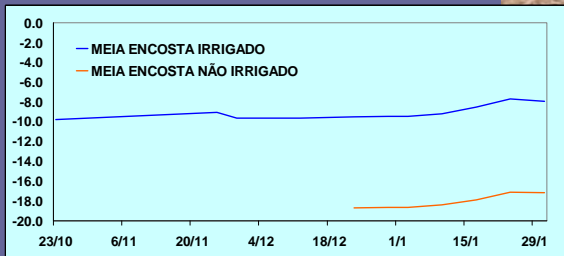
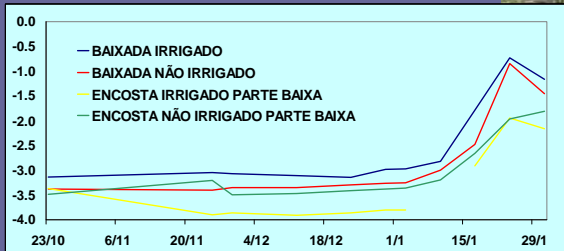
$$T_{i,j} = ET \cdot K_{ti,j}$$

$$K_{ti,j} = \frac{K_{ri,j}}{\sum_{j=1}^n K_{ri,j}} \cdot \frac{K_{si,j}}{\sum_{j=1}^n K_{si,j}}$$

$$K_{ri,j} = \frac{(0,9prf_{i,j})}{100} + \frac{(0,1prm_{i,j})}{100}$$

$$K_{si,j} = \frac{(\theta_{ij} - \theta_{PMP})}{(\theta_{cc} - \theta_{PMP})}$$

$$ARM_i = ARM_{i-1} + P_i - T_i - Es_i - Id_i - Is_i + ESCe_i - ESCs_i - EXC_i + ASC_i$$



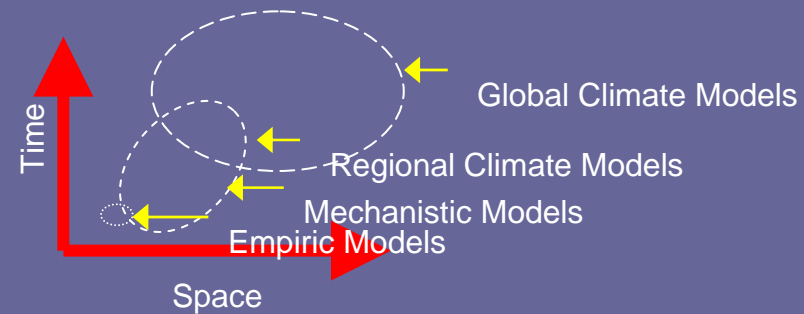
## WATER TABLE MEASUREMENTS



## WATER GET IN/OUT THE ROOT ZONE



# MECHANISTIC MODELS

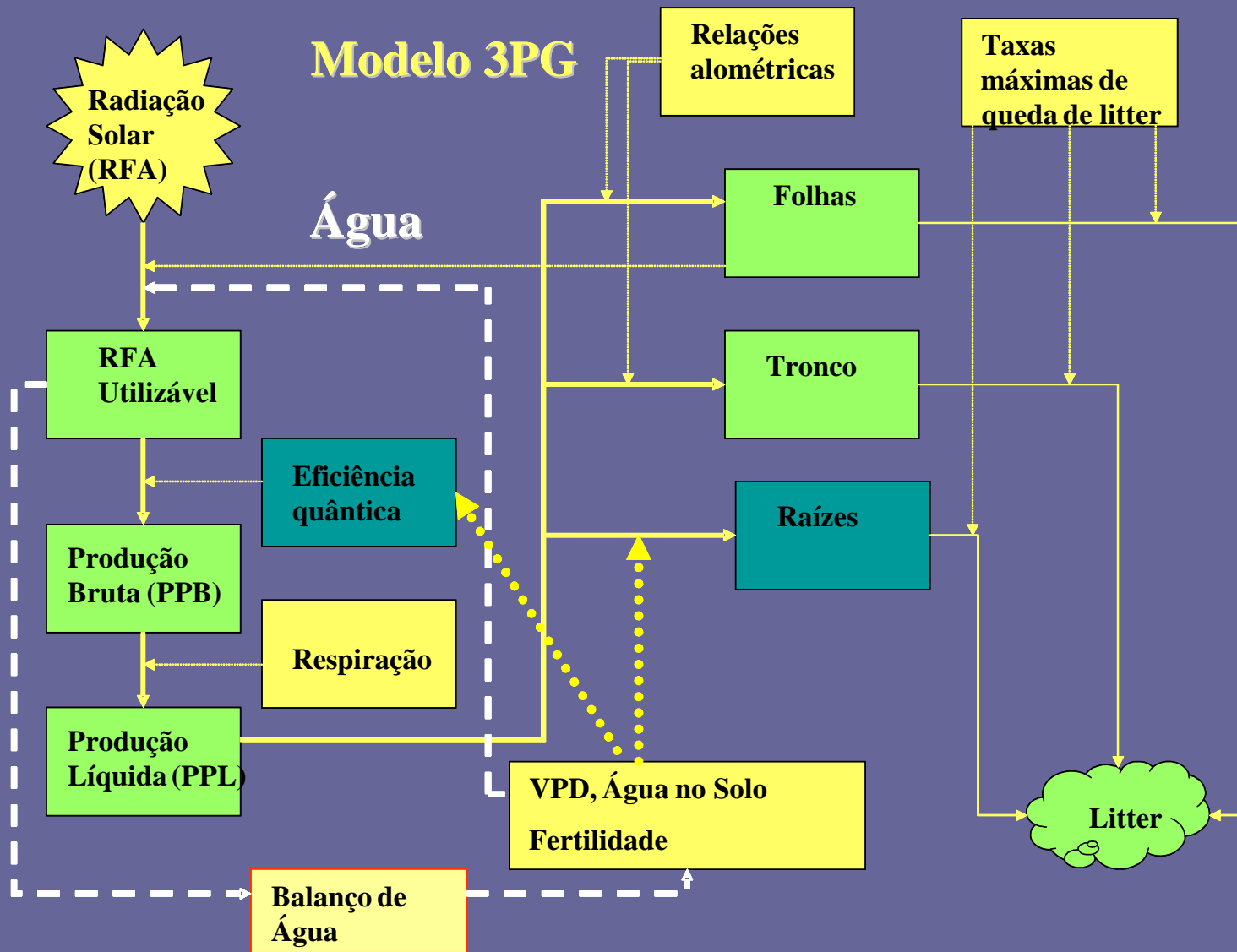


1. Today ecophysiological models are useful to forestry planning activities; in a average stated period it will be useful to operational decision taking
2. Production pattern changes can be predict with ecophysiological models due changes in the genetic, climatic and forestry manager factors
3. The accuracy of ecophysiological models depends of observational experiments, more and more complex with knowledge profit

There are many forestry mechanistic models: LINKAGES, CENTURY, FOREST-BCG, MAESTRO, BIOMASS, BEX, TREGROW, PnET e 3-PG.

WHAY 3-PG?





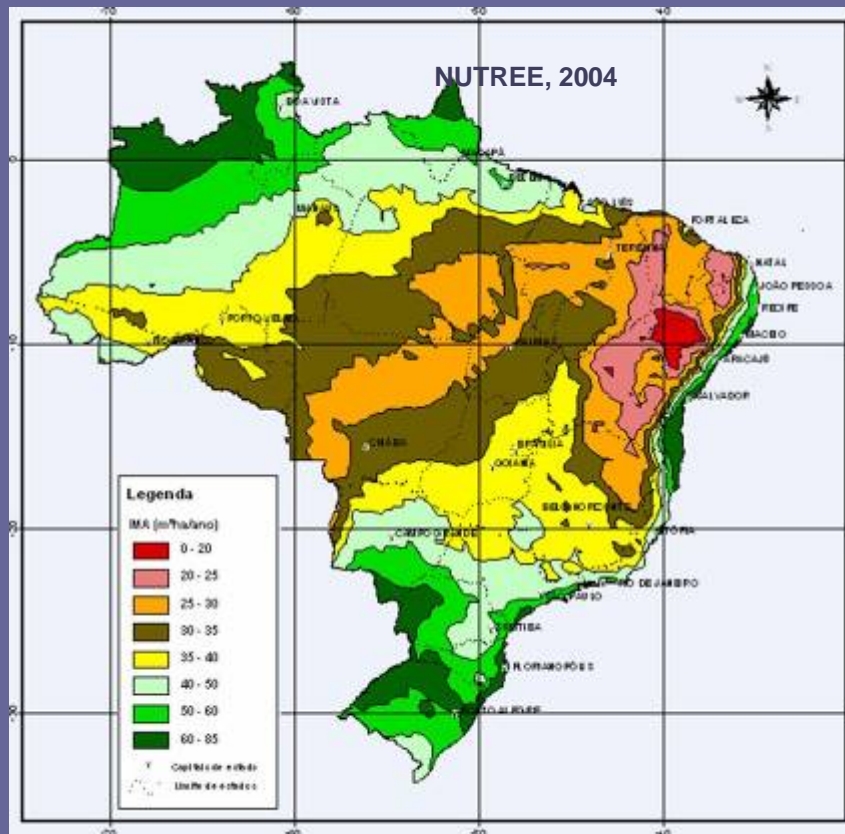
$$GPP = APAR \cdot \alpha^* \cdot f_W \cdot f_N \cdot f_D$$

$\alpha^*$  = Maxima Eficiencia Quantica da Copa

$f_i$ : Restricoes a Fotossintese: agua no solo, fertilidade, VPD

$\alpha$  aparente =  $\alpha^* \cdot f_i$

# CLIMATE CHANGE AND FORESTRY

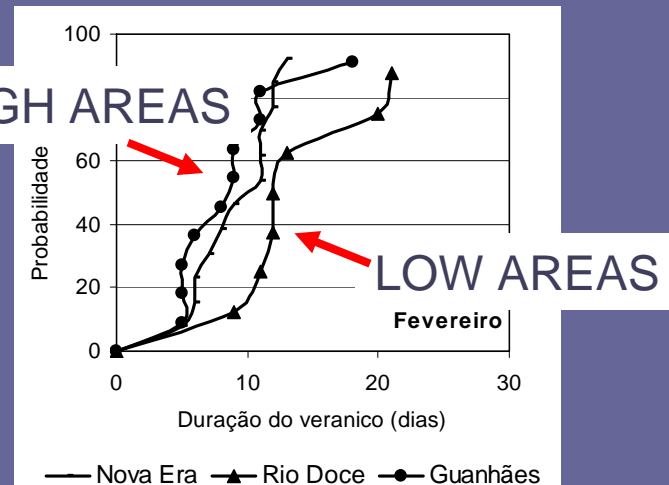
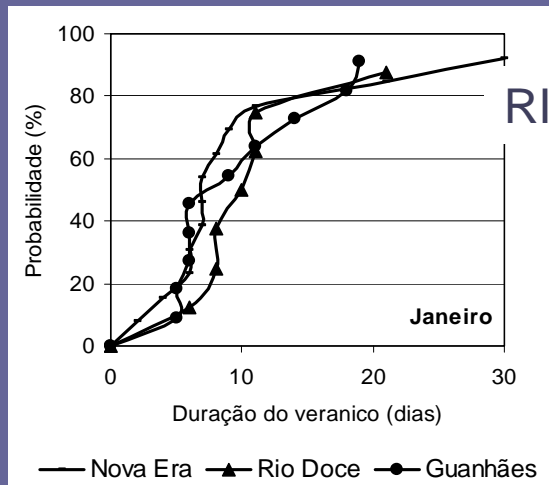
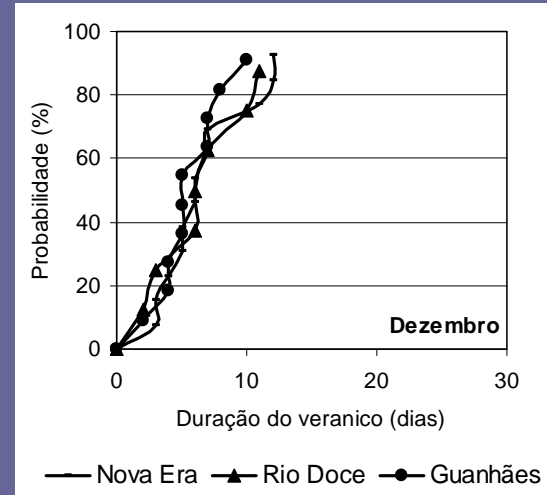
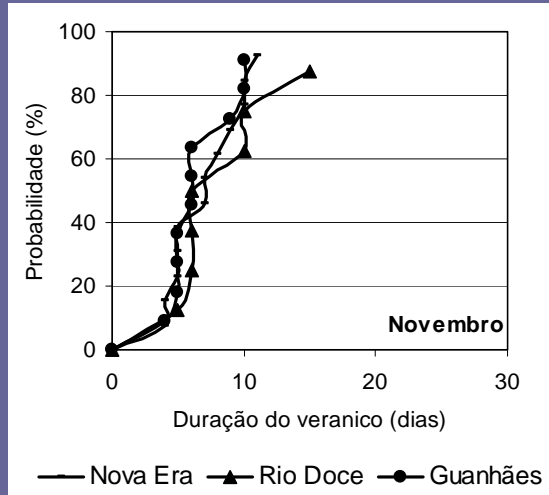


**GROWTH MODELS  
PLANNING TOOL**

**NOT ONLY ON  
PRODUCTION, BUT  
ENVIRONMENTAL  
IMPACTS ALSO.**

**WHICH WOULD  
BE THE IMPACTS  
IN FORESTRY?**

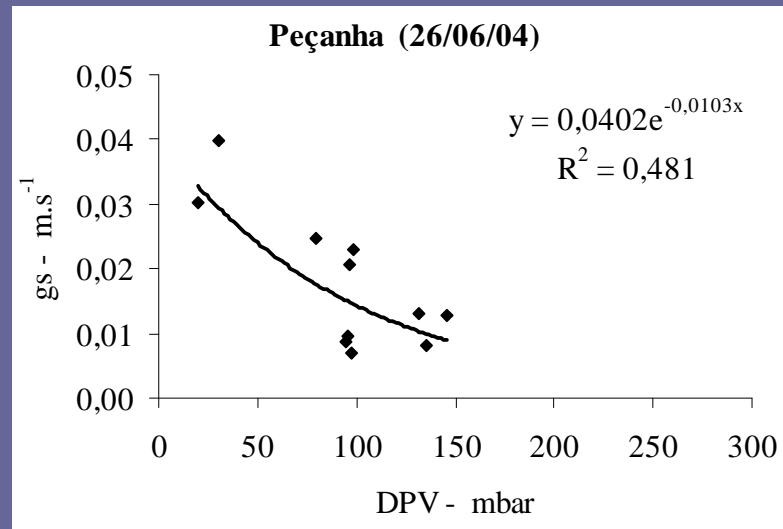
# VERANICOS DURATION PROBABILITY OF EVENTS SUMMER (RAINY PERIOD) RIO DOCE BASIN



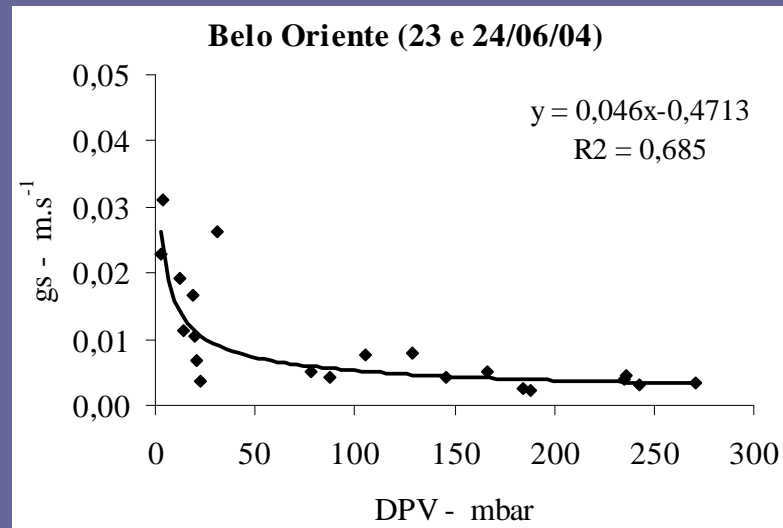
# STOMATIC CONDUCTANCE x VDP

The Case of Rio Doce Basin

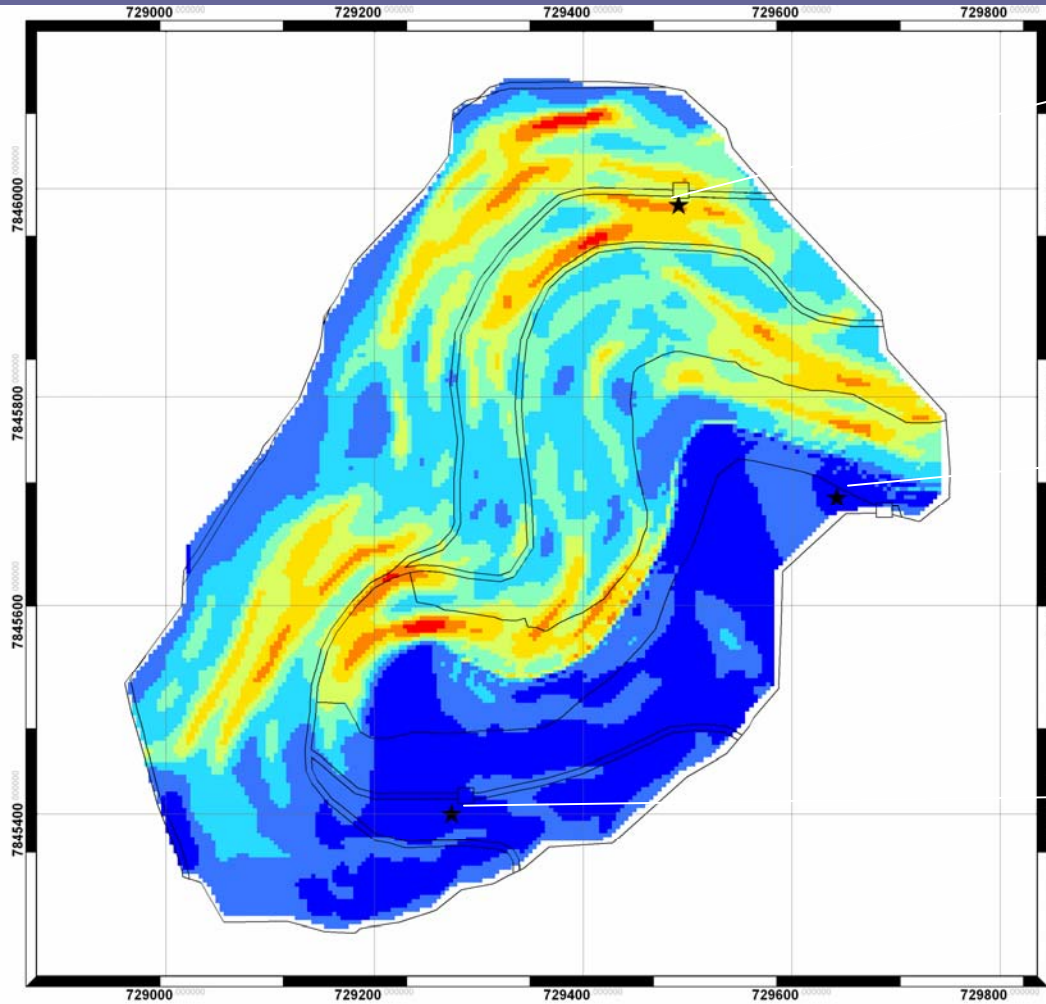
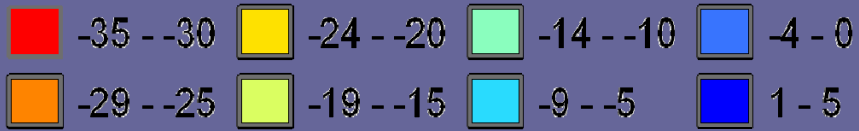
1200 m



250 m



# BIOMASS



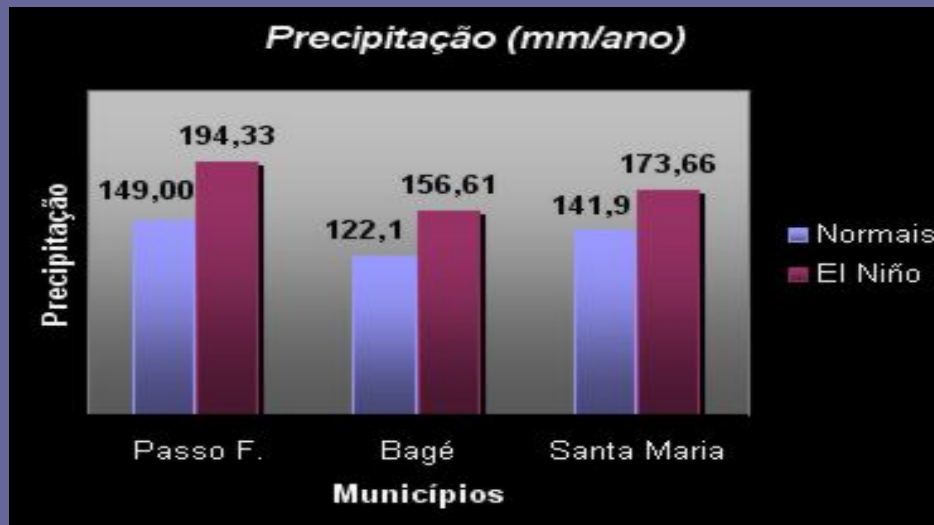
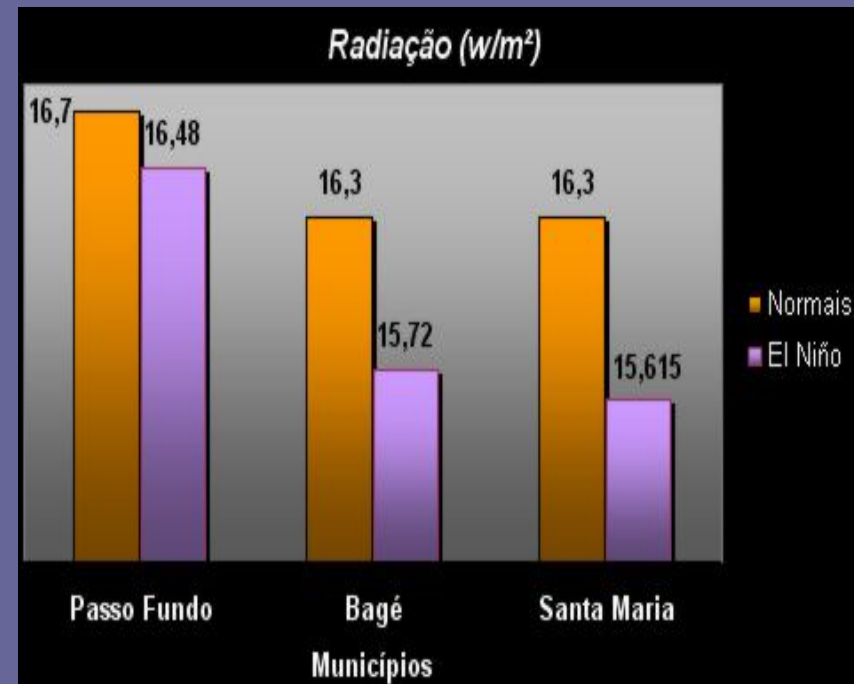
↑ LAI

↓ LAI

# 3PG SIMULATION CLIMATOLOGY AND EL NIÑO YEARS

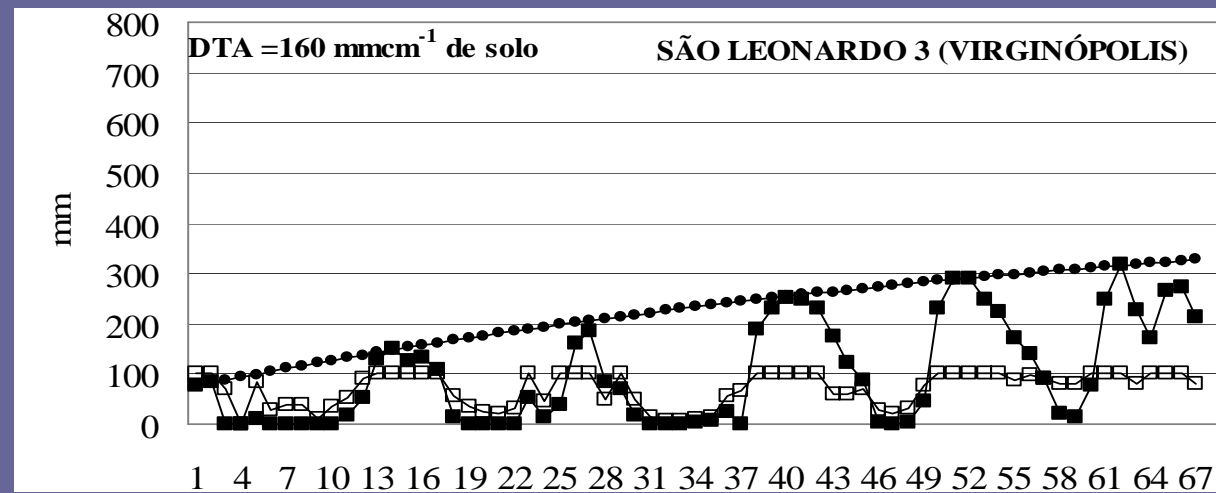
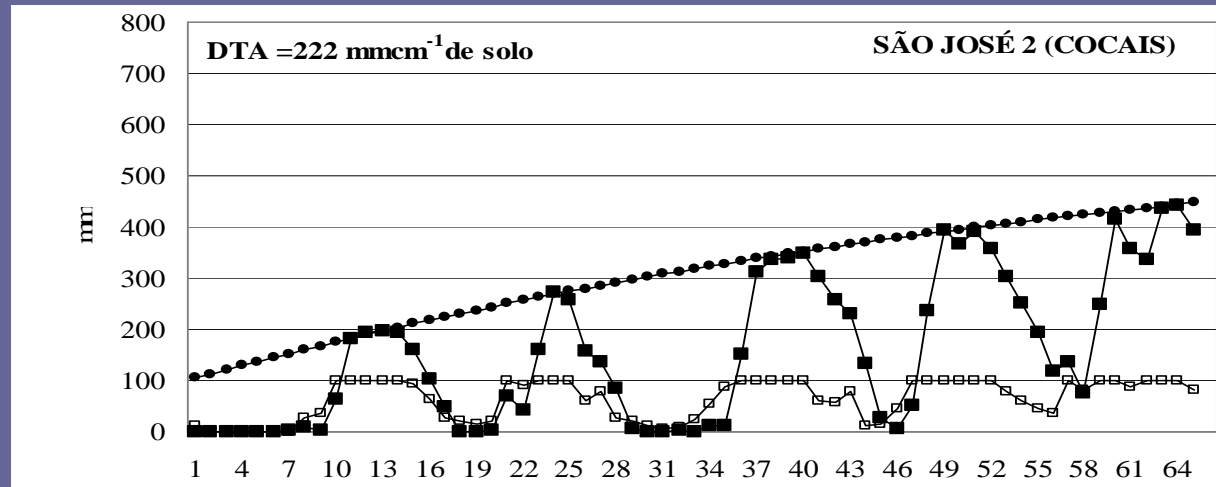
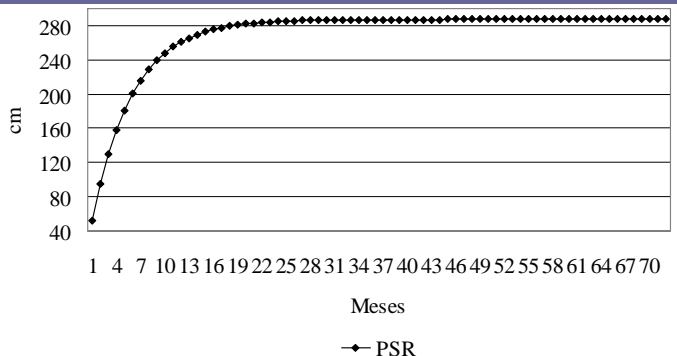


## RIO GRANDE DO SUL - BRAZIL SEVEN YEAR EUCALYPTUS PRODUCTION CYCLE



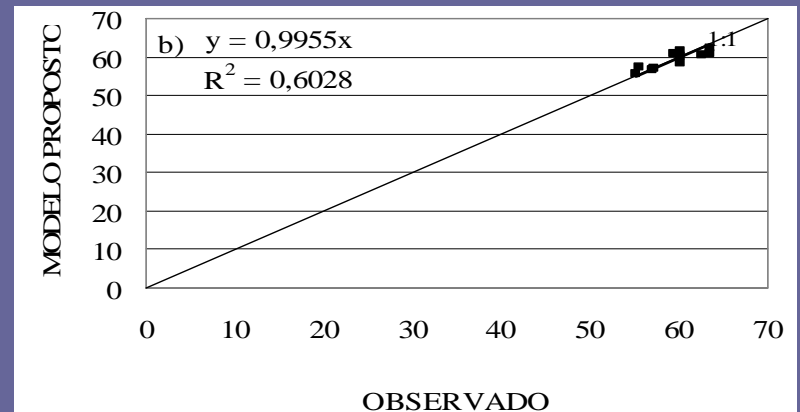
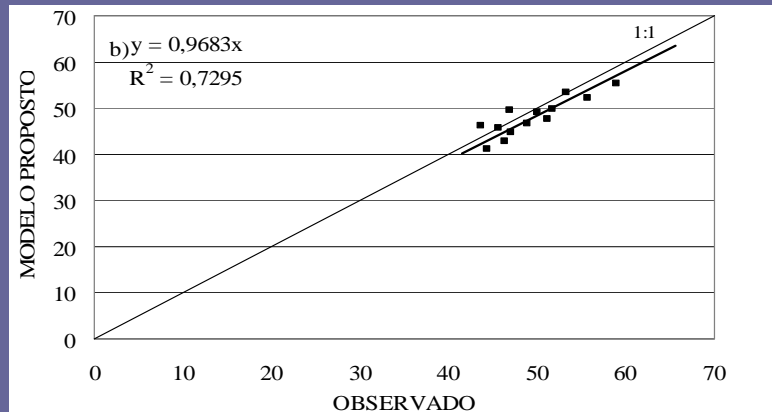
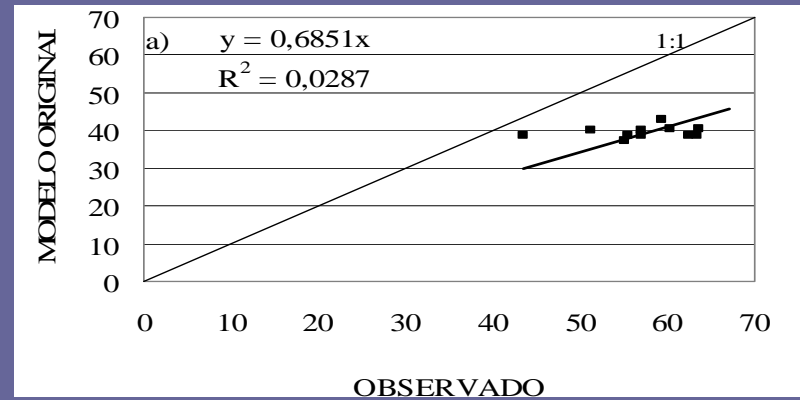
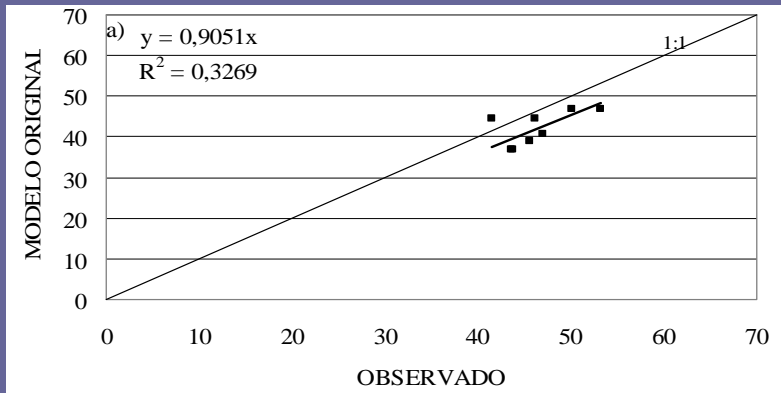


# WATER STORAGE IN THE ROOT LAYER



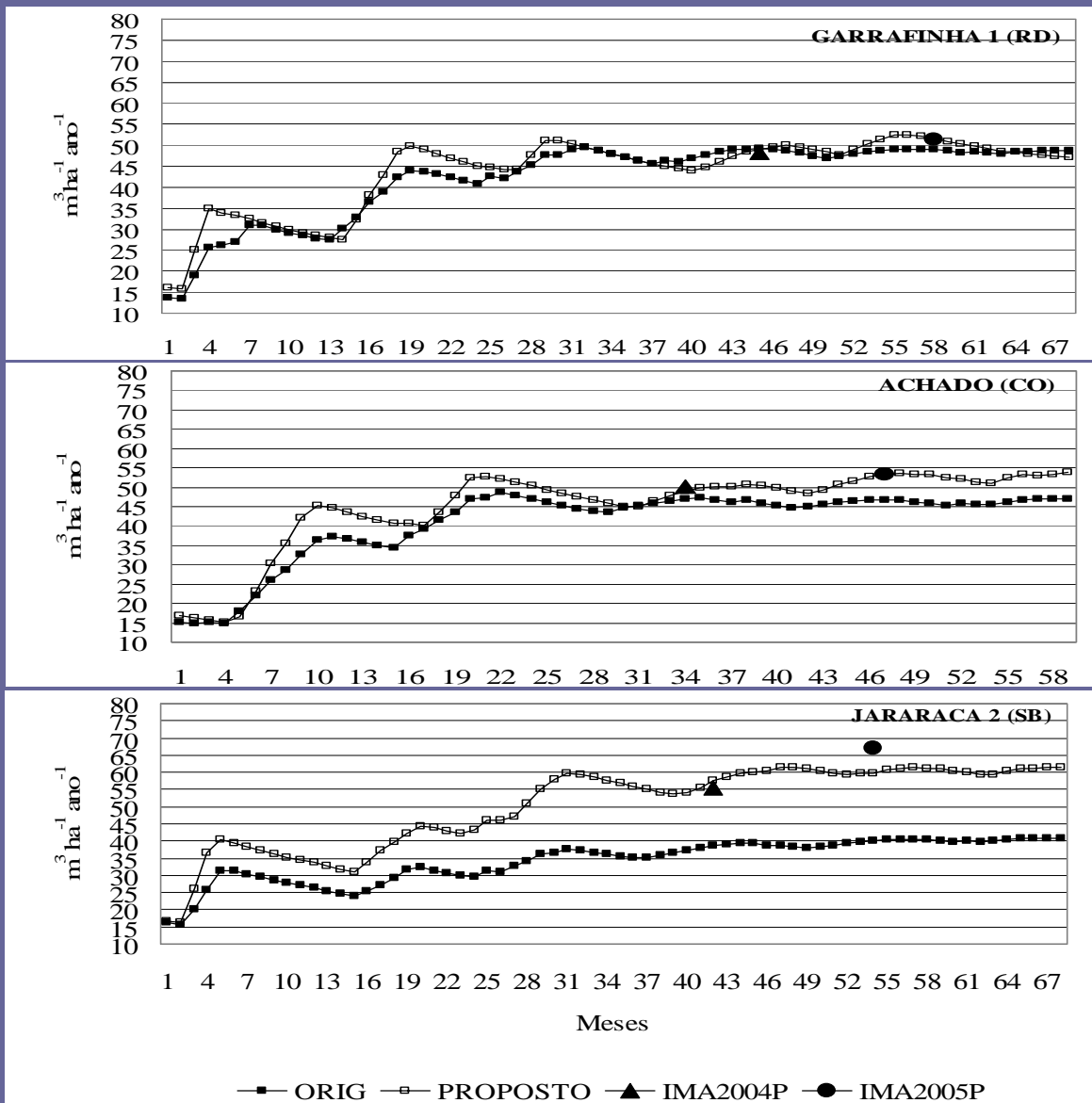
## ROOT DEPTH VARIATION

# MODEL ADJUSTMENT



MAI observed and modeled for Cocais and Belo Oriente regions  
1200 e 250 m

# AJUSTE DO MODELO



**Avaliar os impactos das mudanças climáticas na produção florestal de eucalipto no Brasil por meio da simulação do modelo 3-PG associado a dois cenários de mudanças climáticas para três períodos futuros: 2011-2040, 2041-2070 e 2071-2100.**

**Evangelista (2006)**

**Dados Observados**

**CRU**  
Resolução:  
**0.5° latitude/longitude**

**Dados Modelados**

**CCSR/NIES GCM e Hardley Center**  
Resolução: **5.6° latitude/longitude**

**A2**

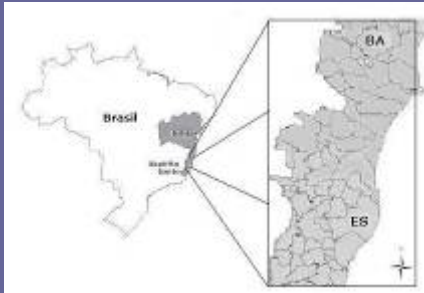
**B2**

**Períodos de Tempo**

**(2011-2040) (2041-2070) (2071-2100)**

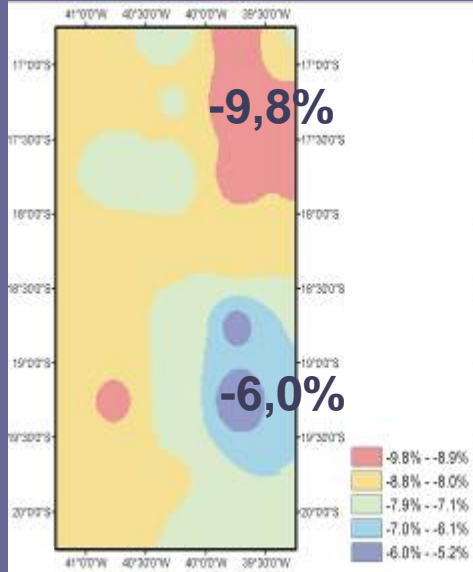
**Downscaling**  
Resolução: **0.5° latitude/longitude**

# Variação Percentual do Incremento Médio Anual ( $\text{m}^3 \text{ha}^{-1} \text{ano}^{-1}$ ) CCSR/NIES

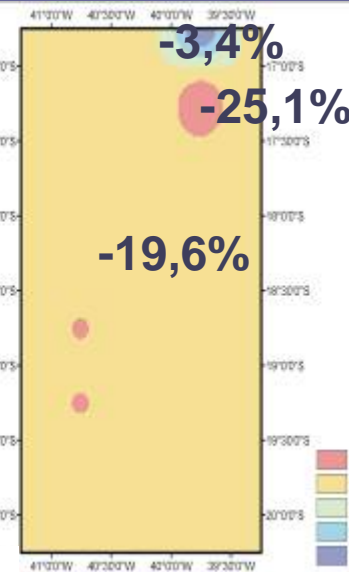


Cenário A2

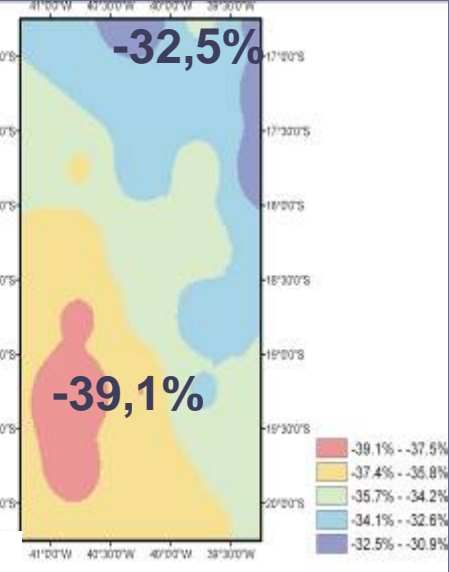
2011-2040



2041-2070

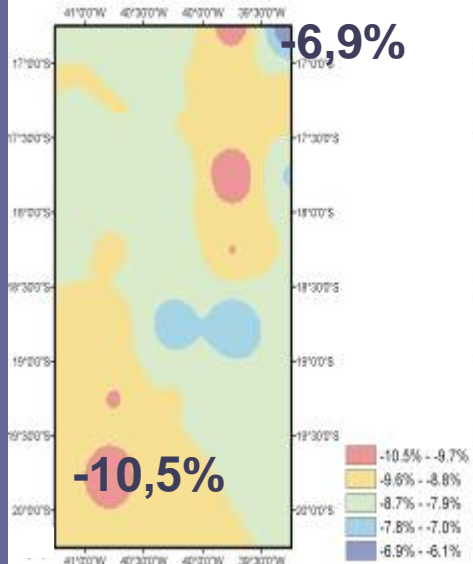


2071-2100

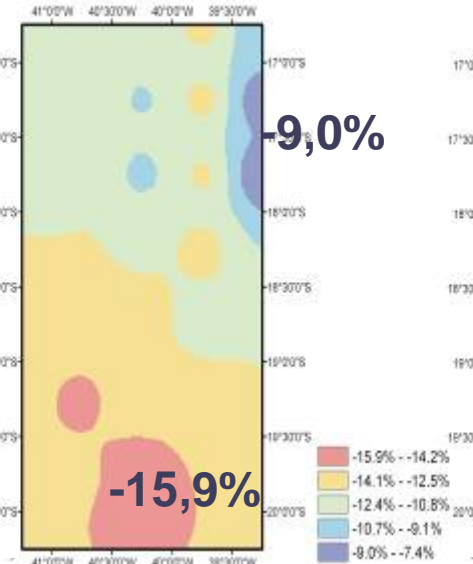


Cenário B2

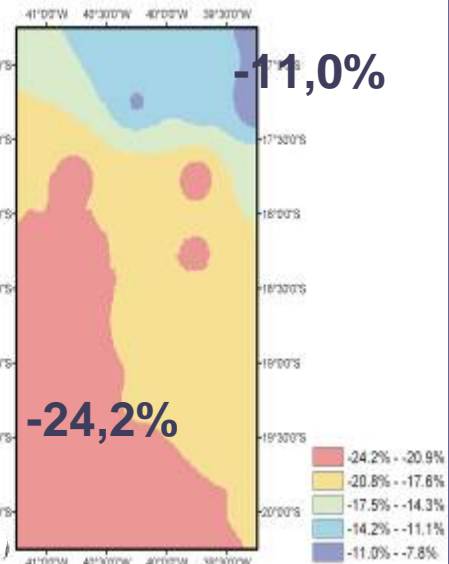
2011-2040



2041-2070



2071-2100





# 3PG SIMULATION CONSIDERING THE FERTILIZING OF CO<sub>2</sub>



17°15'S 39°15'W



17°15'39.15'W

Prado

336 m

Image © 2007 DigitalGlobe  
© 2007 MapLink/TeleAtlas  
Image © 2007 TerraMetrics

© 2007 Google

Ponteiro 17°15'13.98" S 39°15'00.04" O elev 34 m Fluxo 100% Altitude do ponto de visão 1.30 km

BR-439

Prado

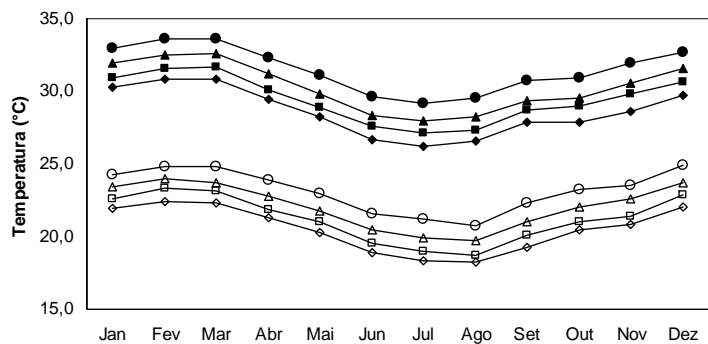
4.62 km

Image © 2007 DigitalGlobe  
© 2007 MapLink/TeleAtlas  
Image © 2007 TerraMetrics  
© 2007 Europa Technologies

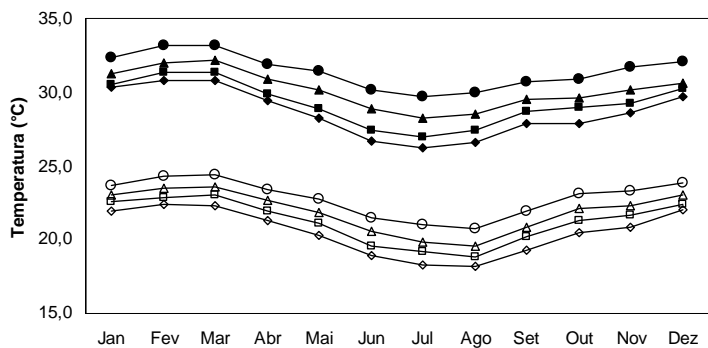
© 2007 Google



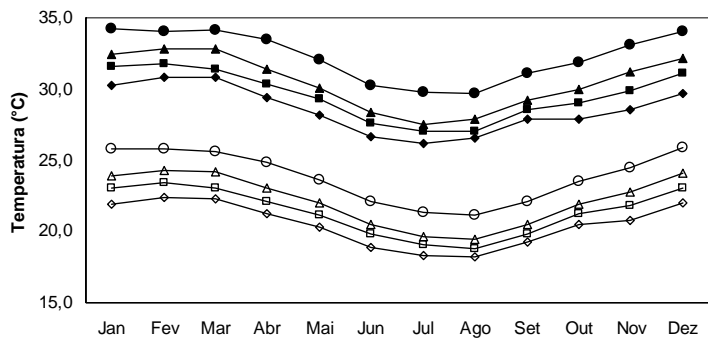
Cenário A2\_CSIRO GCM



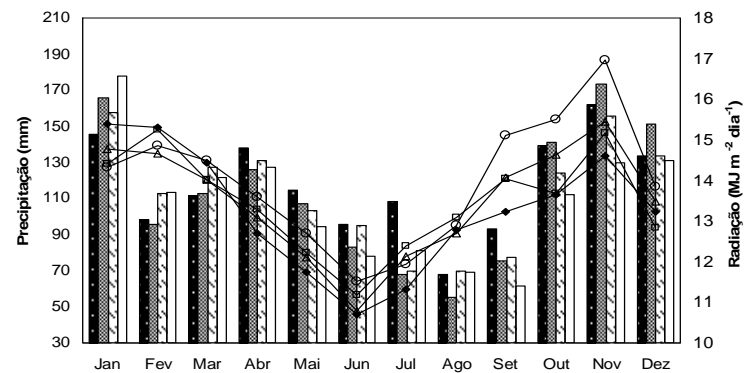
Cenário A2\_HADCM3 GCM



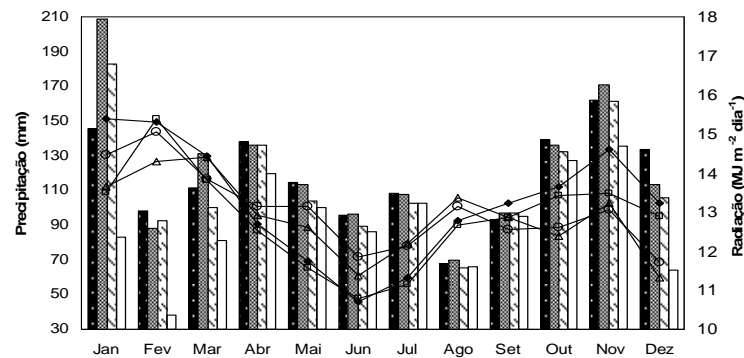
Cenário A2\_CCSR/NIES GCM



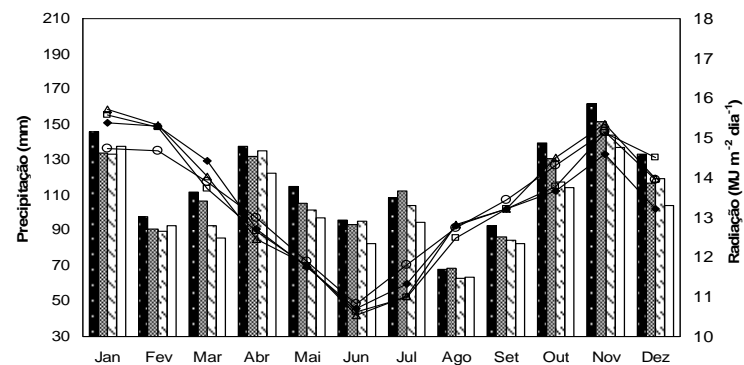
Cenário A2\_CSIRO GCM



Cenário A2\_HADCM3 GCM

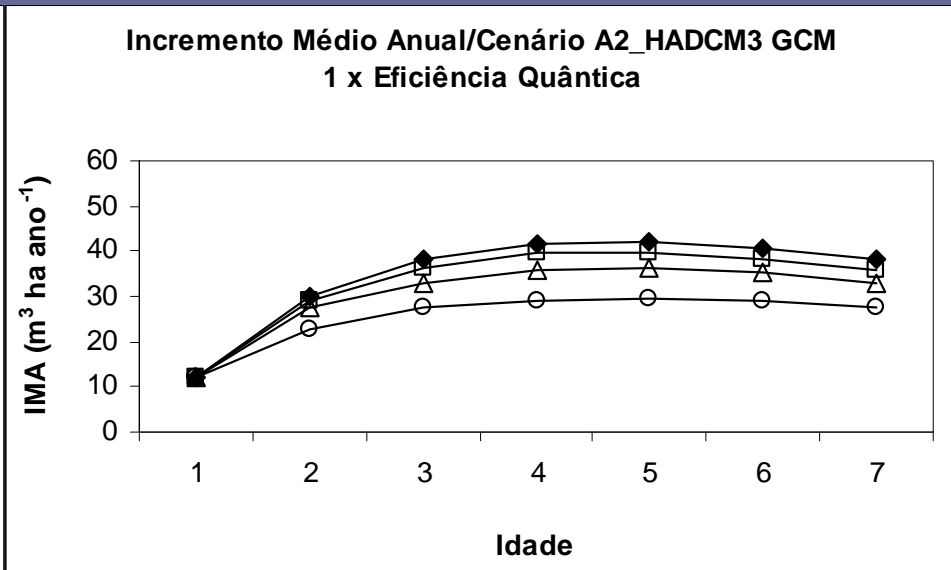
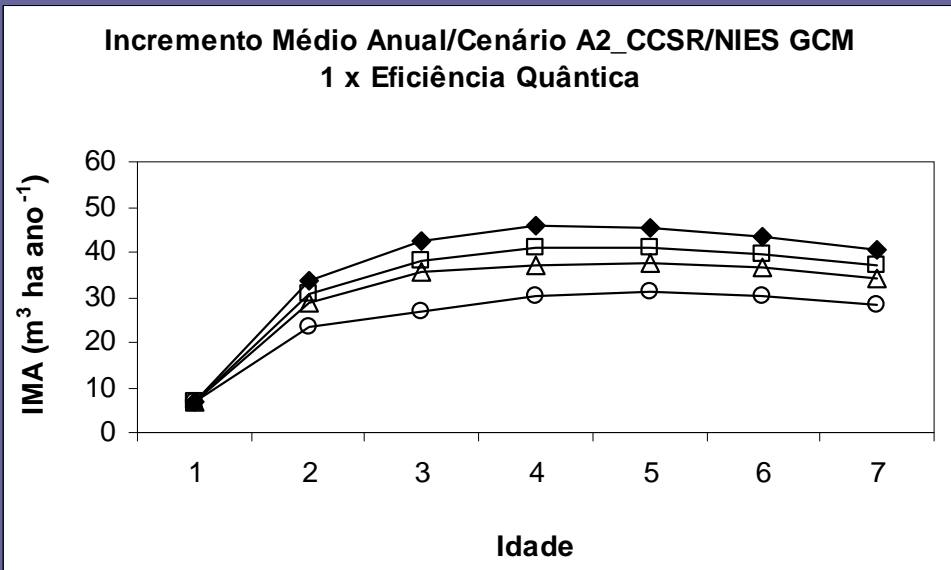
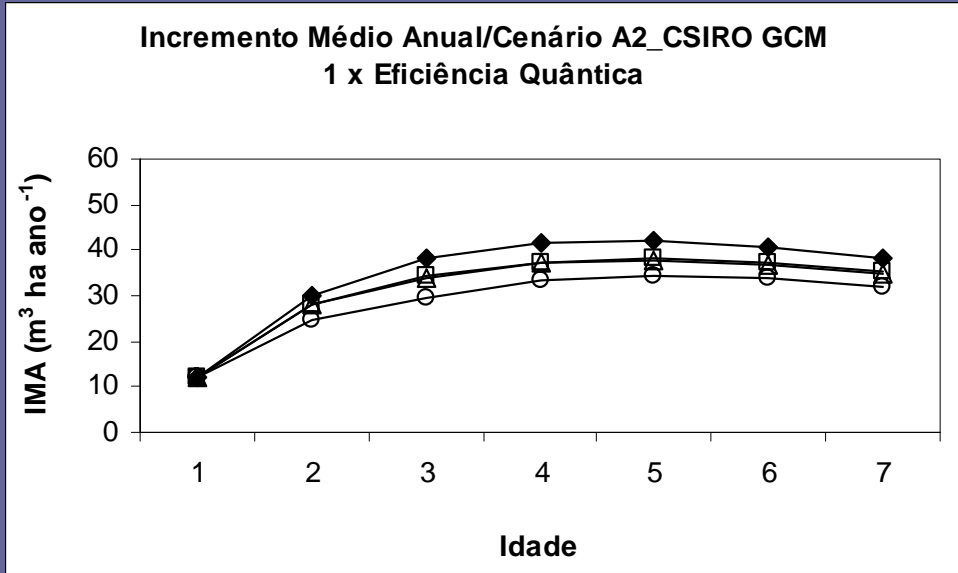


Cenário A2\_CCSR/NIES GCM

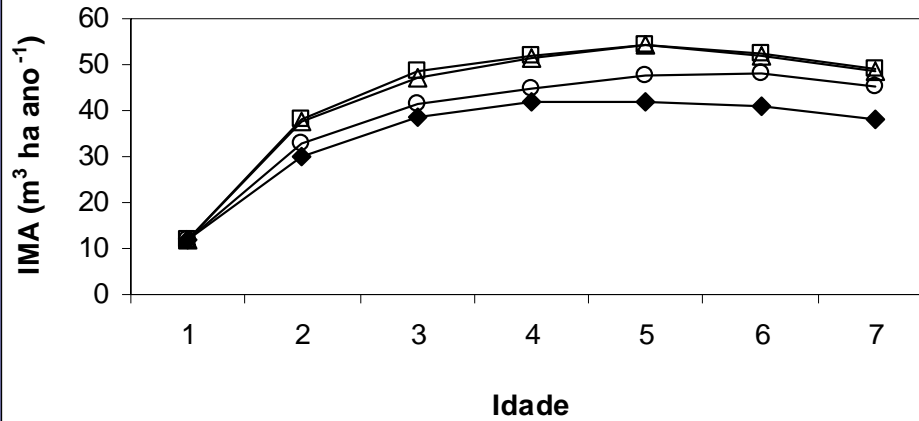


—●— Tm<sub>x</sub>\_1961-1990 "Atual"    —■— Tm<sub>x</sub>\_A2 2011-2040    —▲— Tm<sub>x</sub>\_A2 2041-2070  
 —●— Tm<sub>x</sub>\_A2 2071-2100    —◇— Tm<sub>n</sub>\_1961-1990 "Atual"    —□— Tm<sub>n</sub>\_A2 2011-2040  
 —▲— Tm<sub>n</sub>\_A2 2041-2070    —◇— Tm<sub>n</sub>\_A2 2071-2100

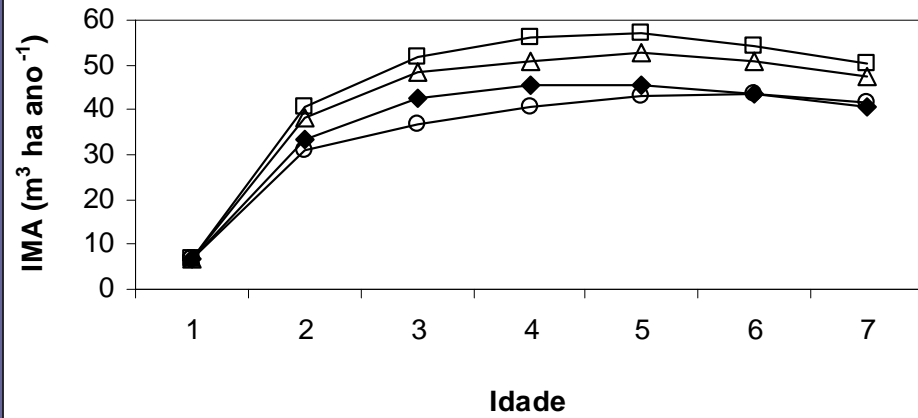
—■— Prec\_1961-1990 "Atual"    —▨— Prec\_A2 2011-2040    —□— Prec\_A2 2041-2070  
 —□— Prec\_A2 2071-2100    —▲— Rad\_1961-1990 "Atual"    —□— Rad\_A2 2011-2040  
 —▲— Rad\_A2 2041-2070    —◇— Rad\_A2 2071-2100



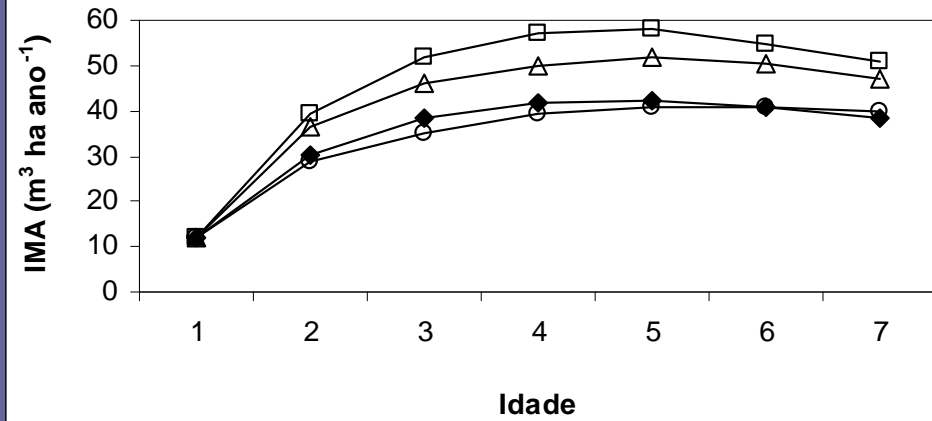
**Incremento Médio Anual/Cenário A2\_CSIRO GCM  
1,33 x Eficiência Quântica**



**Incremento Médio Anual/Cenário A2\_CCSR/NIES GCM  
1,33 x Eficiência Quântica**



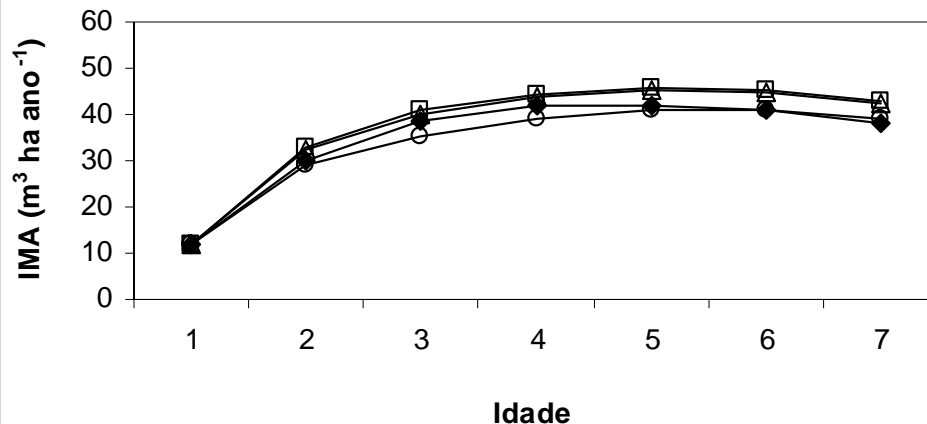
**Incremento Médio Anual/Cenário A2\_HADCM3 GCM  
1,33 x Eficiência Quântica**



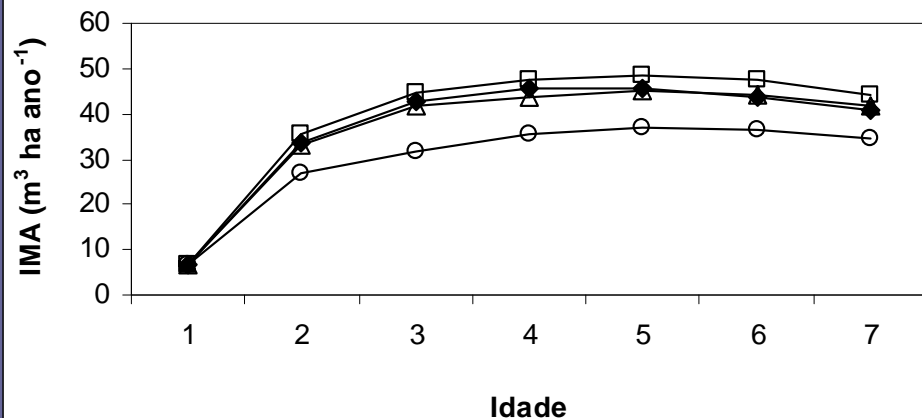
◆ IMA\_Atual  
 ▲ IMA\_2041-2070

□ IMA\_2011-2040  
 ○ IMA\_2071-2100

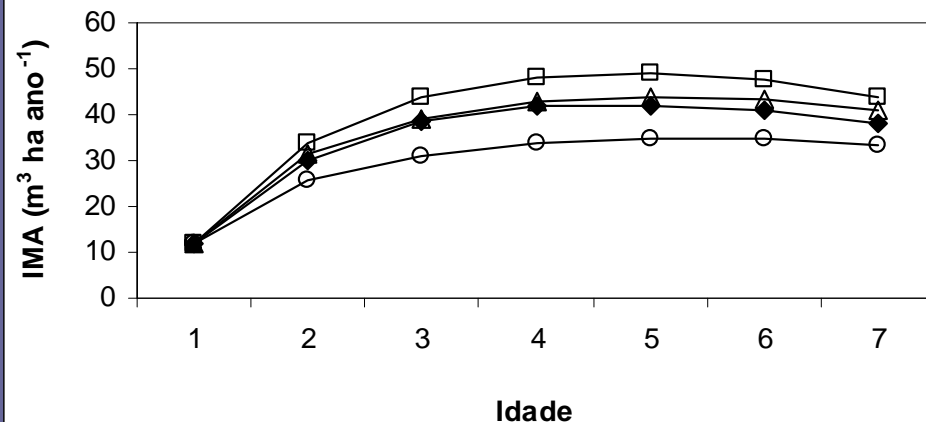
**Incremento Médio Anual/Cenário A2\_CSIRO GCM  
1,17 x Eficiência Quântica**



**Incremento Médio Anual/Cenário A2\_CCSR/NIES GCM  
1,17 x Eficiência Quântica**



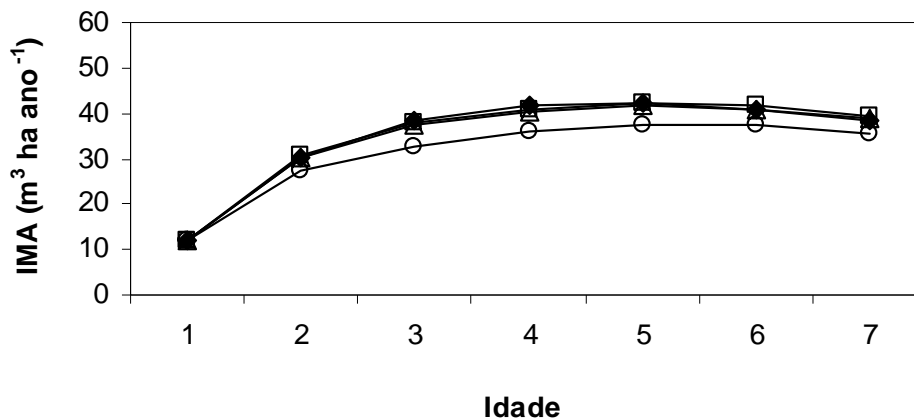
**Incremento Médio Anual/Cenário A2\_HADCM3 GCM  
1,17 x Eficiência Quântica**



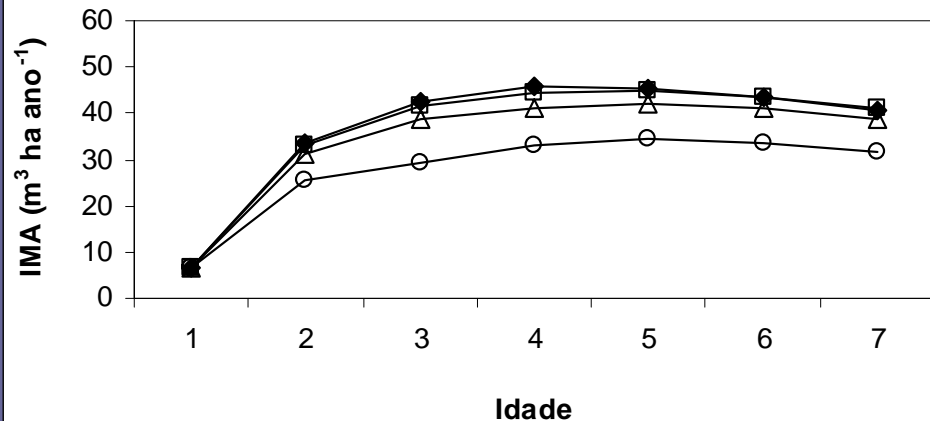
—■— IMA\_Atual  
—△— IMA\_2041-2070

—□— IMA\_2011-2040  
—○— IMA\_2071-2100

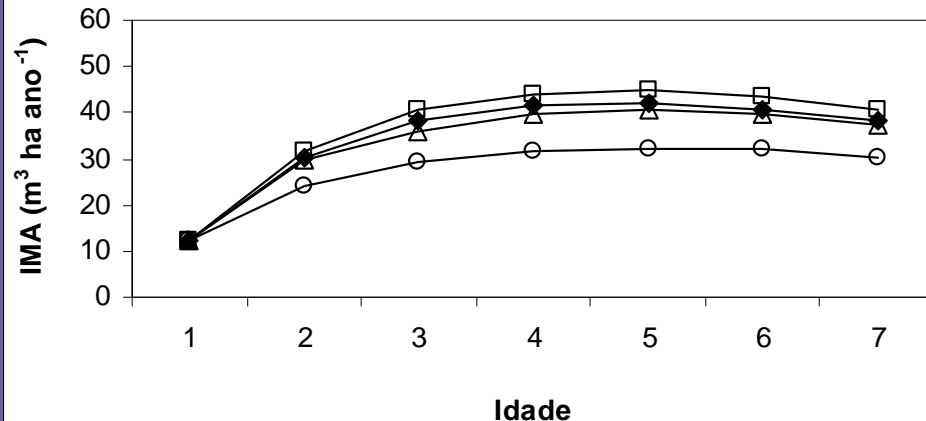
**Incremento Médio Anual/Cenário A2\_CSIRO GCM  
1,08 x Eficiência Quântica**



**Incremento Médio Anual/Cenário A2\_CCSR/NIES GCM  
1,08 x Eficiência Quântica**



**Incremento Médio Anual/Cenário A2\_HADCM3 GCM  
1,08 x Eficiência Quântica**

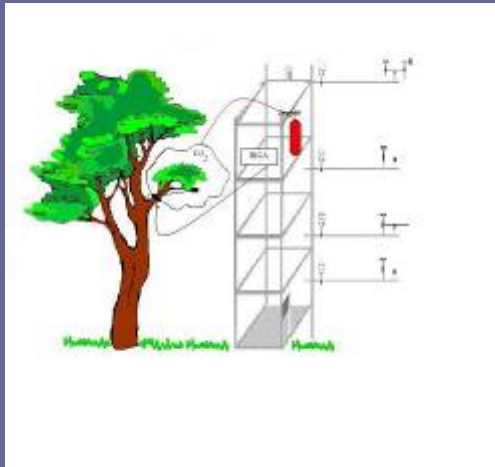
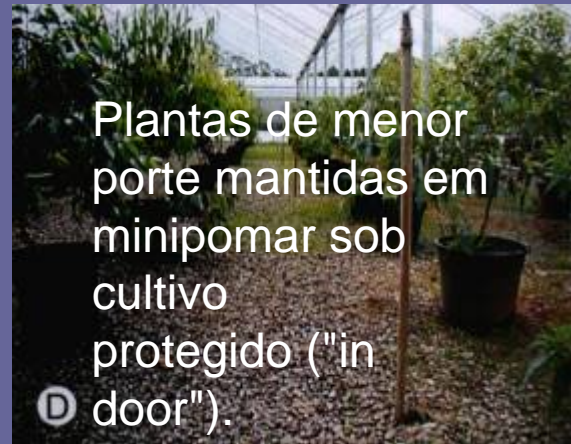
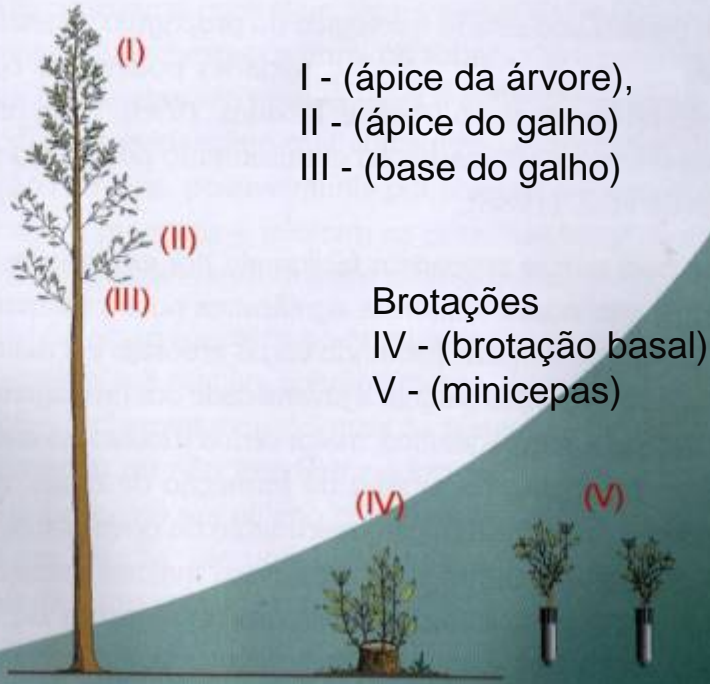


◆ IMA\_Atual  
 ▲ IMA\_2041-2070

□ IMA\_2011-2040  
 ○ IMA\_2071-2100

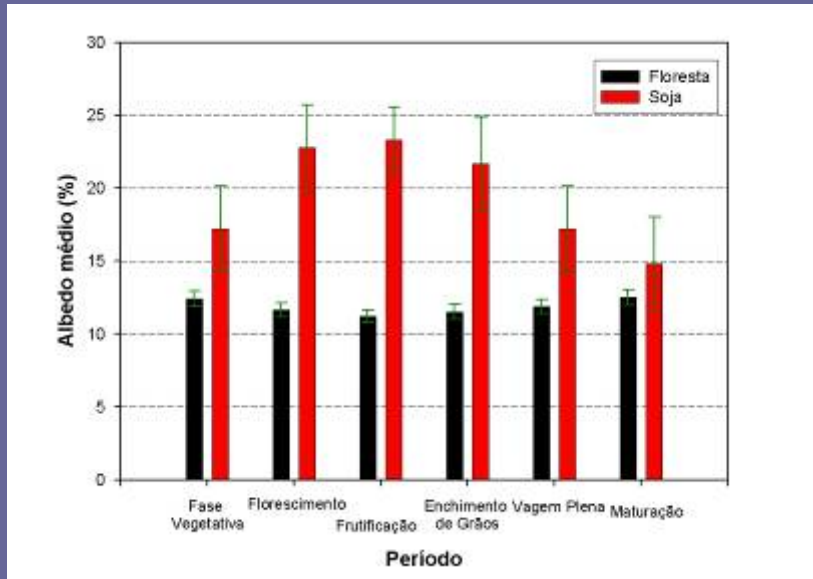
# STUDY OF CO<sub>2</sub> FERTILIZING

## GRADIENTE CRESCENTE DE JUVENILIDADE



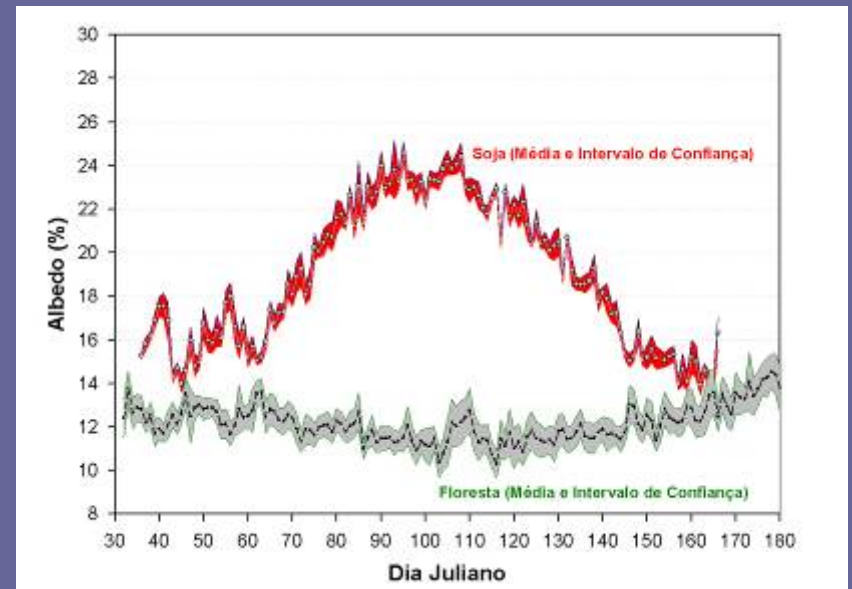
Field measurements

# IMPACTS OF LAND USE CHANGE ON REGIONAL CLIMATE



## SOJA – Paragomina-PA

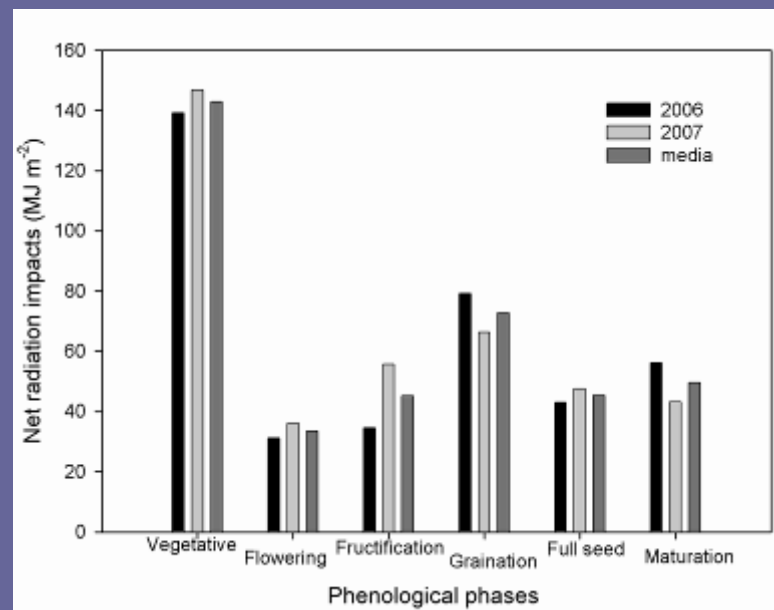
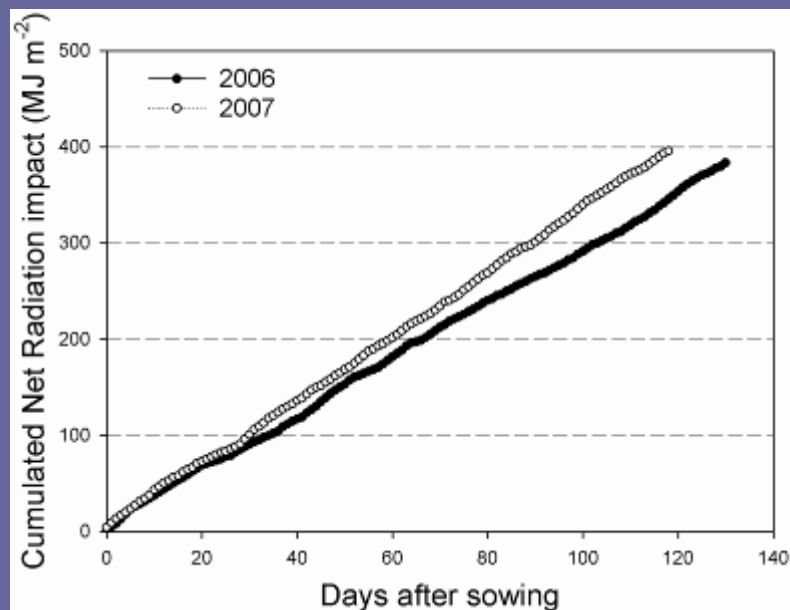
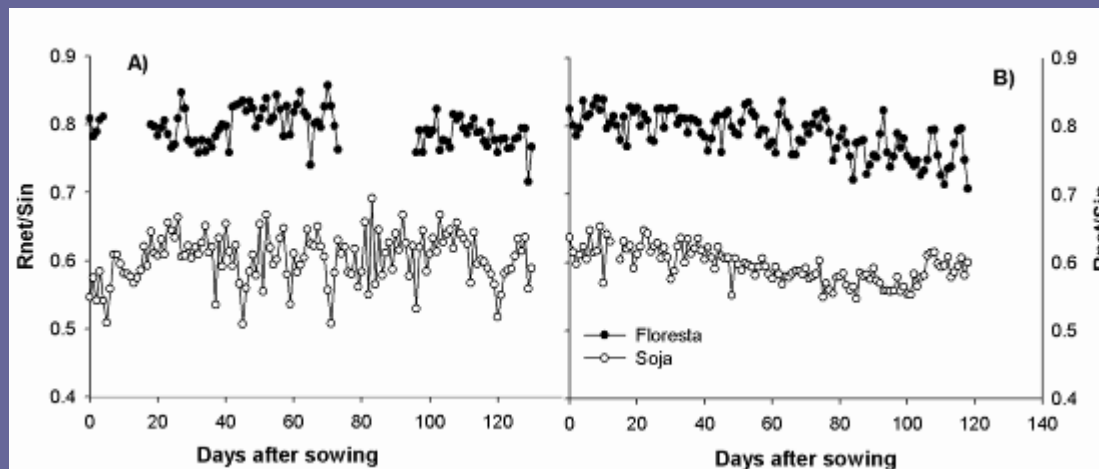
P. J. Ponte de Souza, 2007





# IMPACTS OF LAND USE CHANGE ON REGIONAL CLIMATE

Normalização



**and more ...**

## **INCREASE OF THE**

- 1. FORESTRY AREA IN BRAZIL**
- 2. SUGAR CANE AREA IN CERRADO**
- 3. SOYBEEN IN AMAZONIAN BORDER**

**AND ITS IMPACTS ON THE REGIONAL  
CLIMATE BY CHANGE BIOSPHERE-  
ATMOSPHERE EXCHANGE PATTERNS**

# Conclusões

- No Brasil, ainda não existem estudos sobre os impactos das mudanças climáticas na produção florestal e nos países desenvolvidos estes esforços de pesquisa são ainda recentes.
- Existem incertezas no grau de previsibilidade dos modelos climáticos, existindo atualmente mais de 20 modelos climáticos globais em operação. Neste contexto, para minimizar possíveis erros deve-se escolher para criar os cenários, diferentes modelos abrangendo previsões mais e menos otimistas de grupos de pesquisa respeitados no mundo. Ainda para o ajuste de escala ou downscaling da previsão em escala global ( 300 a 600 Km de resolução espacial) para escala regional ( 50Km de resolução) pode ser utilizadas técnicas estatística e através de métodos sofisticados pela utilização de modelos regionais.
- As incertezas quanto a modelagem ecofisiológica reside no fato do modelo 3PG não ser ainda sensível a alguns processos, como o efeito denominado de fertilização das plantas C3, no caso o eucalipto, que aumentaria a eficiência fotossintética pelo aumento na concentração de CO<sub>2</sub> atmosférico. Outros processos ainda não bem atendidos são o aumento da respiração de manutenção, devido ao aumento da temperatura do ar atmosférico, e o estímulo de maior fechamento estomático, devido o aumento da concentração de CO<sub>2</sub>.

## Conclusões

- Assim, não se deve esperar, em curto prazo, estimativas precisas dos ganhos ou perdas em produtividade dos plantios florestais, mas deve-se buscar a obtenção de valores prováveis dessas mudanças para auxiliar na tomada de decisão.
- Os ganhos genéticos ao longo do tempo deve ser outro aspecto a ser considerado, uma vez que o manejo florestal tem menor peso, devido a alta tecnologia empregada na condução de florestas pelas empresas do setor. Neste ponto estudos de simulação, como este, permitirão balizar os principais aspectos genéticos a serem considerados para o cenário futuro face às mudanças climáticas, direcionando o trabalho dos geneticistas.

An aerial photograph of a vast, dense forest. The foreground shows a dirt road or path leading into the woods. The trees are tall and thin, creating a textured, green canopy. The sky is filled with large, grey, overcast clouds, with some lighter patches where the sun might be breaking through. The overall mood is serene and natural.

**THANKS**