



# Modelling Forest Growth and Carbon Dynamics:

## *TRIPLEX Model Development and Applications*

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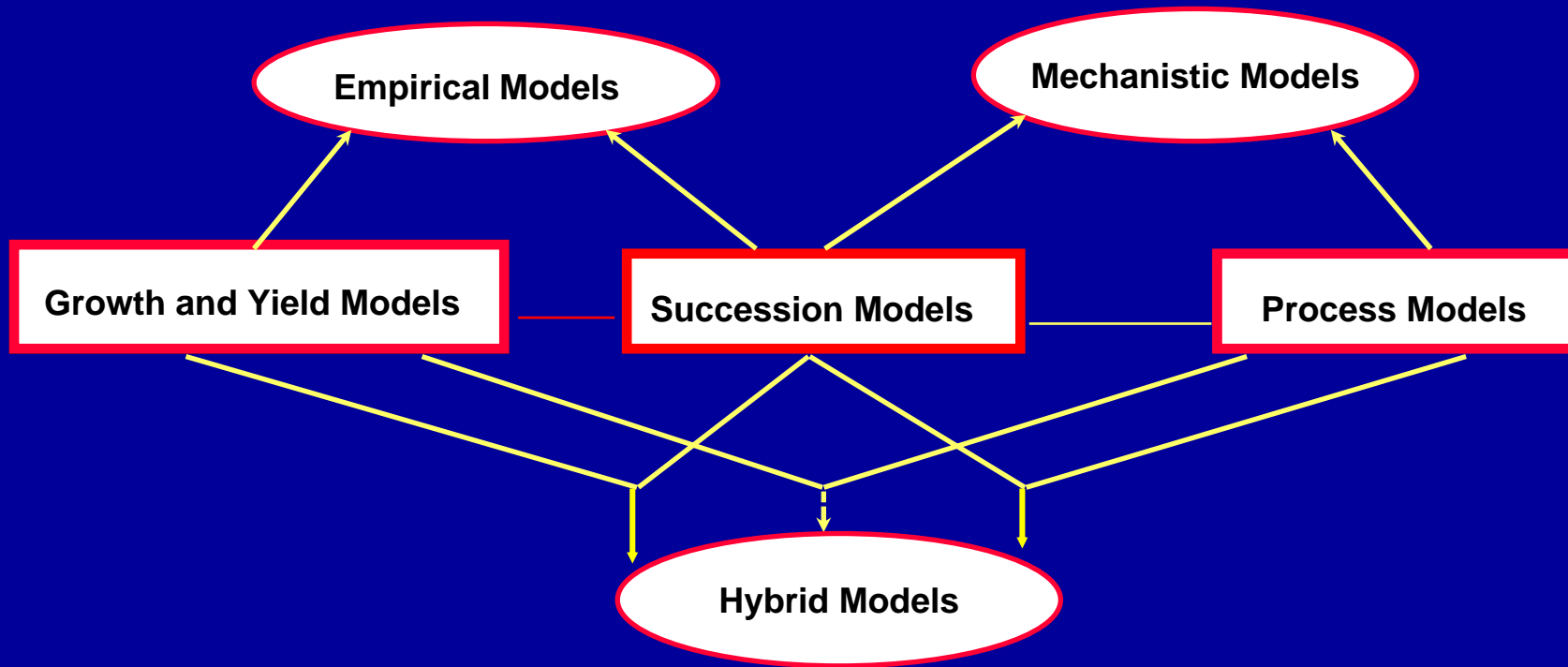
# OUTLINE

- **Overview of TRIPLEX model**
- **TRIPLEX development and testing**
  - TRIPLEX1.0
  - TRIPLEX-Flux
- **Challenges Ahead for TRIPLEX model family development**

# **Major Challenges for Sustainable Forest Management**

- **Sustaining forest ecosystem productivity**
- **Mitigating and/or adapting to the effects of global change**
- **Improving carbon sequestration potential of forests**

# Forest Simulation Models



Increasing ability to predict growth under changed future conditions



Increasing model simulation options and flexibilities

Description



Explanation

(Peng, 2000)

# TRIPLEX: A generic hybrid model for predicting forest growth and carbon and nitrogen dynamics

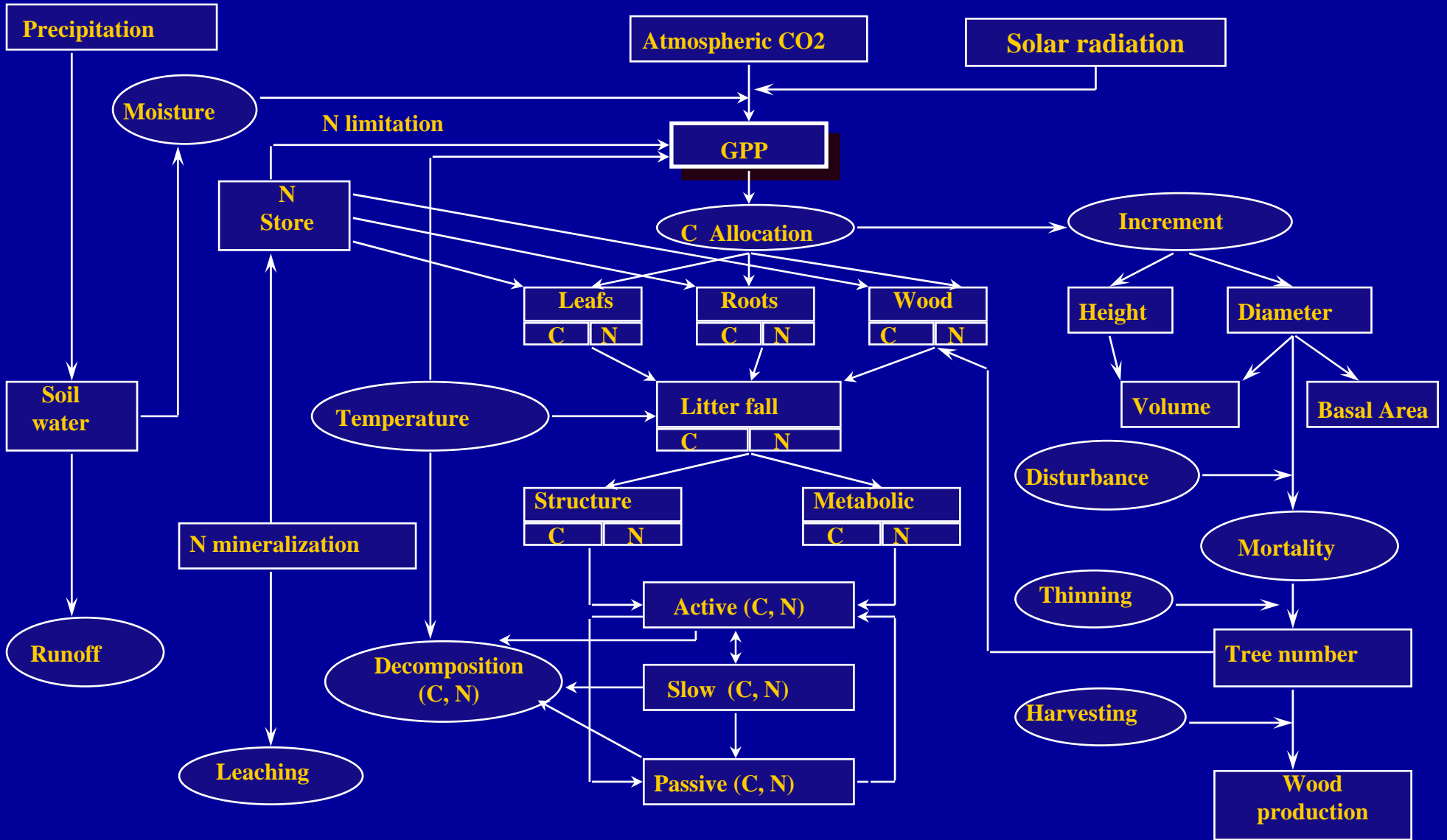
*(Peng et al. 2002, Ecol. Model)*

- **Developed based on well-established models:**
  - 3-PG (Landsberg and Waring, 1997)
  - TREEDYN3.0 (Bossel, 1996)
  - CENTURY4.0 (Parton et al., 1987, 1993)
- **Bridges the gap between forest growth and yield and process-based C balance models**
- **Can be used for:**
  - 1) **Making forest management decisions (e.g., G&Y prediction)**
  - 2) **Quantifying forest carbon budgets**
  - 3) **Assessing the effects of climate change on forest ecosystems**

# Key Features of TRIPLEX1.0:

- **Driving variables (main inputs):**  
**Monthly climate data; tree & stand variables, LAI, soil texture, geo-location**
- **Mass balances:**  
**C, N, and water pools and fluxes fully balanced**
- **Time step:**  
**Monthly C flux and allocation calculation; annual tree growth, C, N, and water budget**
- **Outputs:**  
**H, DBH, BA, volume, NPP, biomass, soil C, N, and water dynamics**
- **Modelling strategy:**  
**OOP (objective-oriented programming - C++) and model reuse approaches**

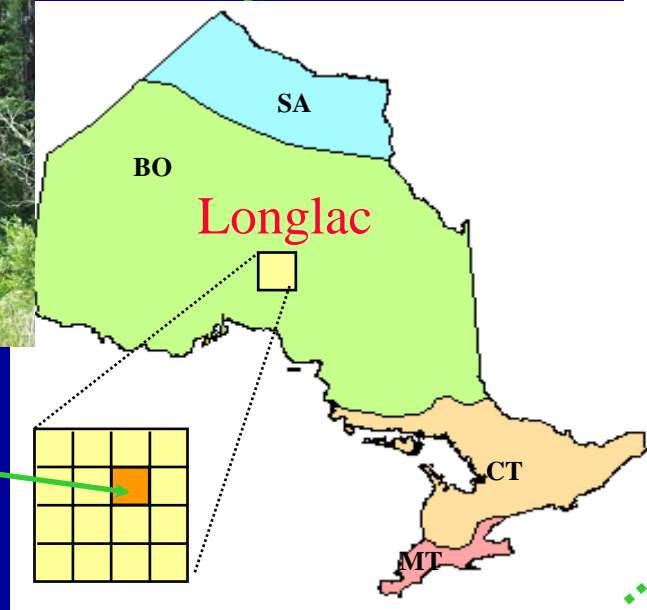
# TRIPLEX1.0 Framework



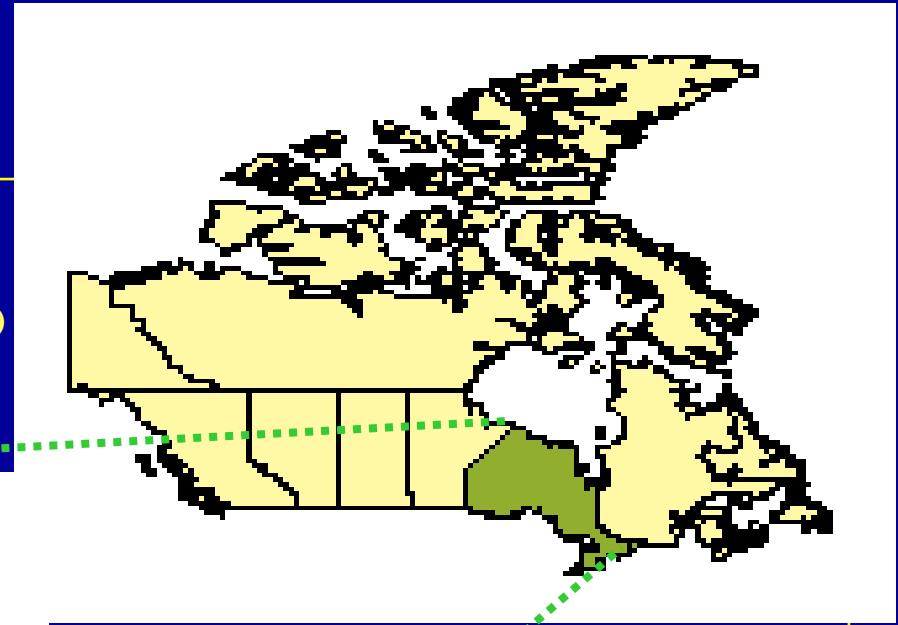
# One Case Study

Location: Longlac (Kimberly Clark Ltd.)

Forest type: Jack pine (*Pinus banksiana* Lamb.)



12 PSP  
(0.08ha  
each)



Ontario

BO: Boreal; CT: Cool Temperate; MT: Moderate Temperate; SA: Subarctic

# Calibration and Validation for TRIPLEX Model

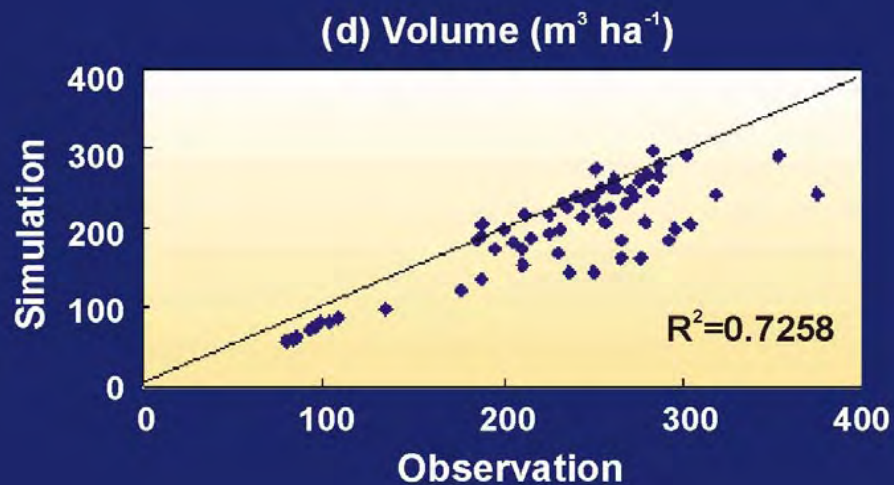
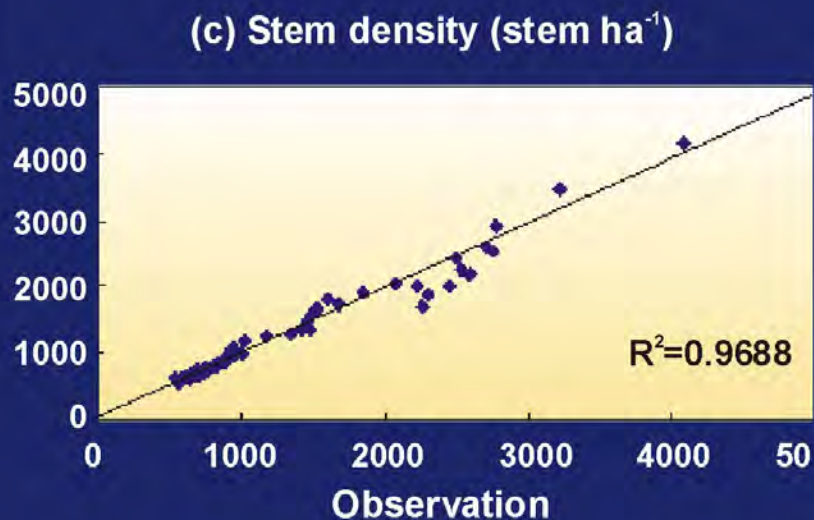
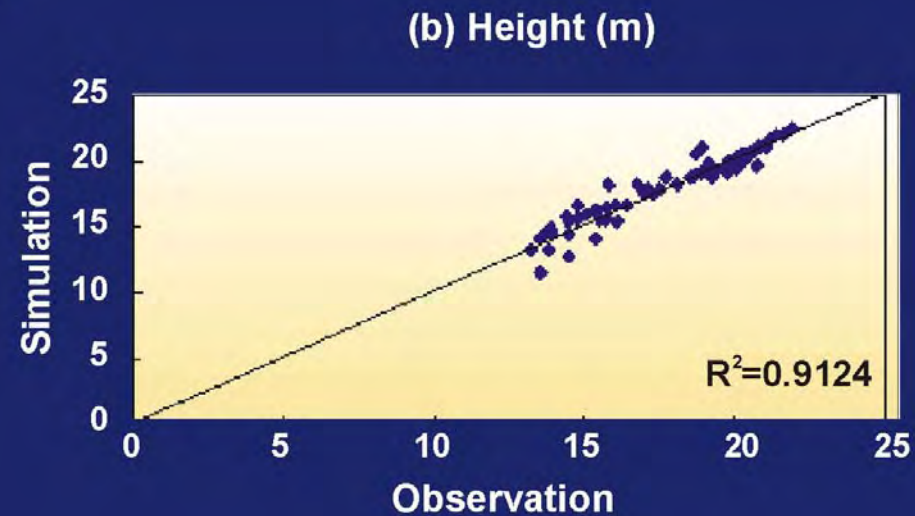
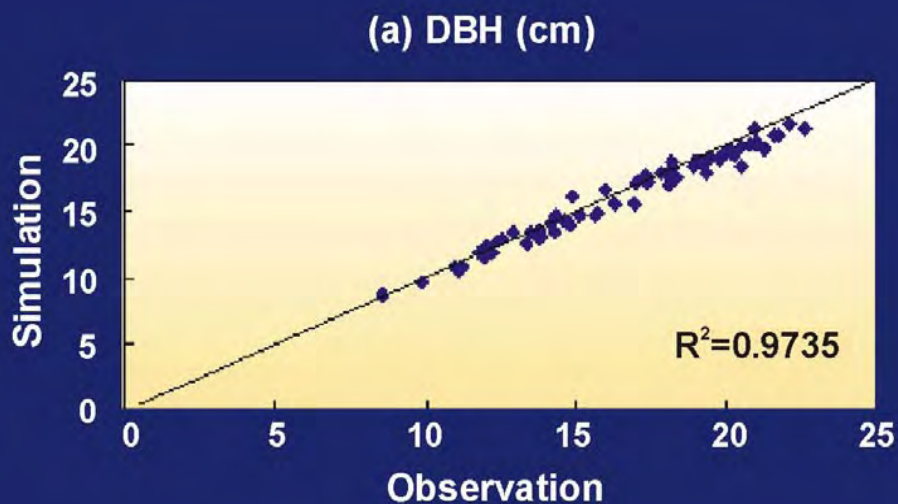
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We have 6 consecutive measurements (every 5 yr) for DBH, H, tree density (1952-1982)

- Use first measurements (1952) to calibrate the TRIPLEX model
- Use the other 5 measurements to validate (1957 - 1982)

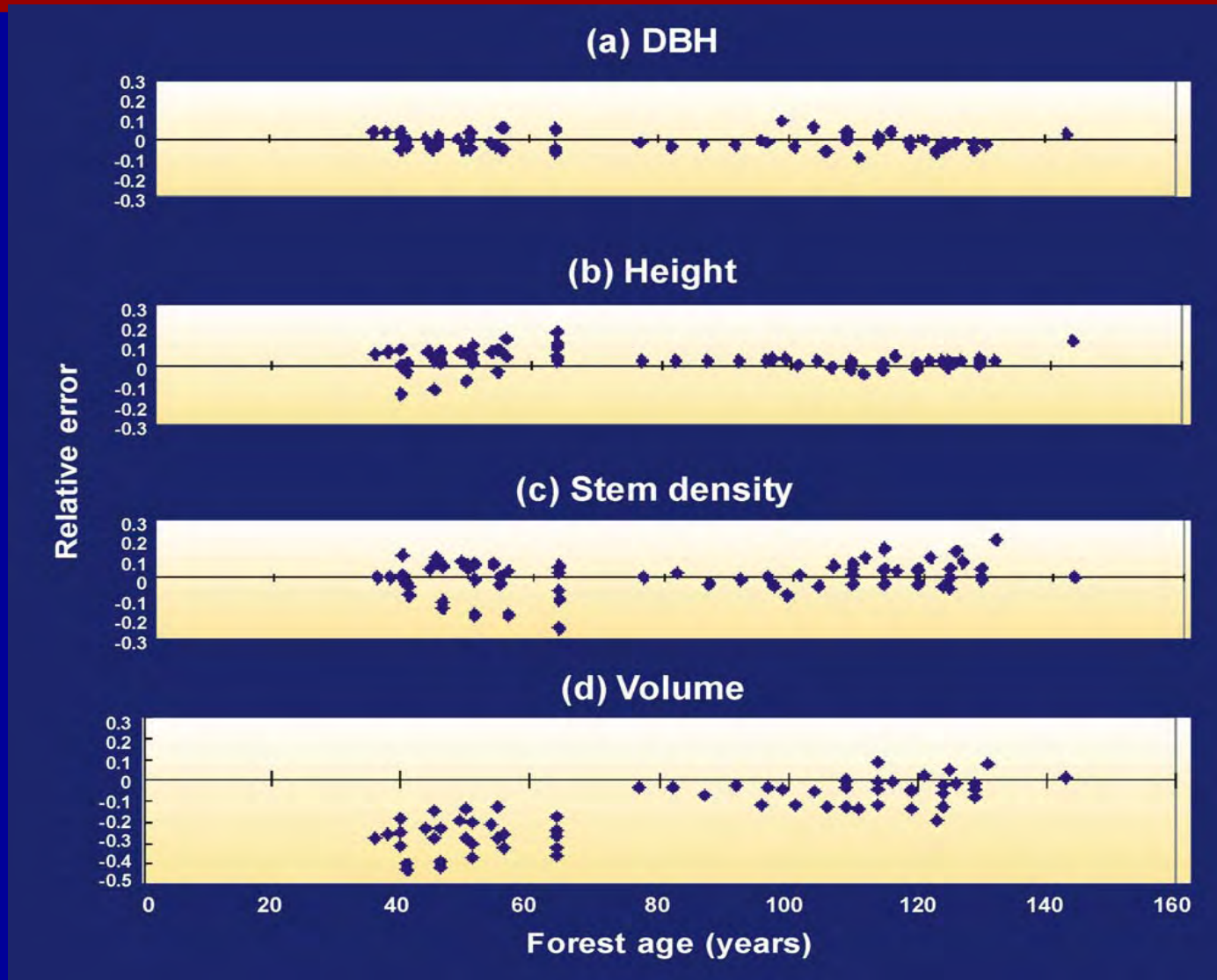
# Comparison of Simulations and Observations

(solid diagonal is the 1:1 line; N=60)



# Simulated Relative Errors for Stand Age

(= $[\text{simulation} - \text{observation}] / \text{observation}$ )



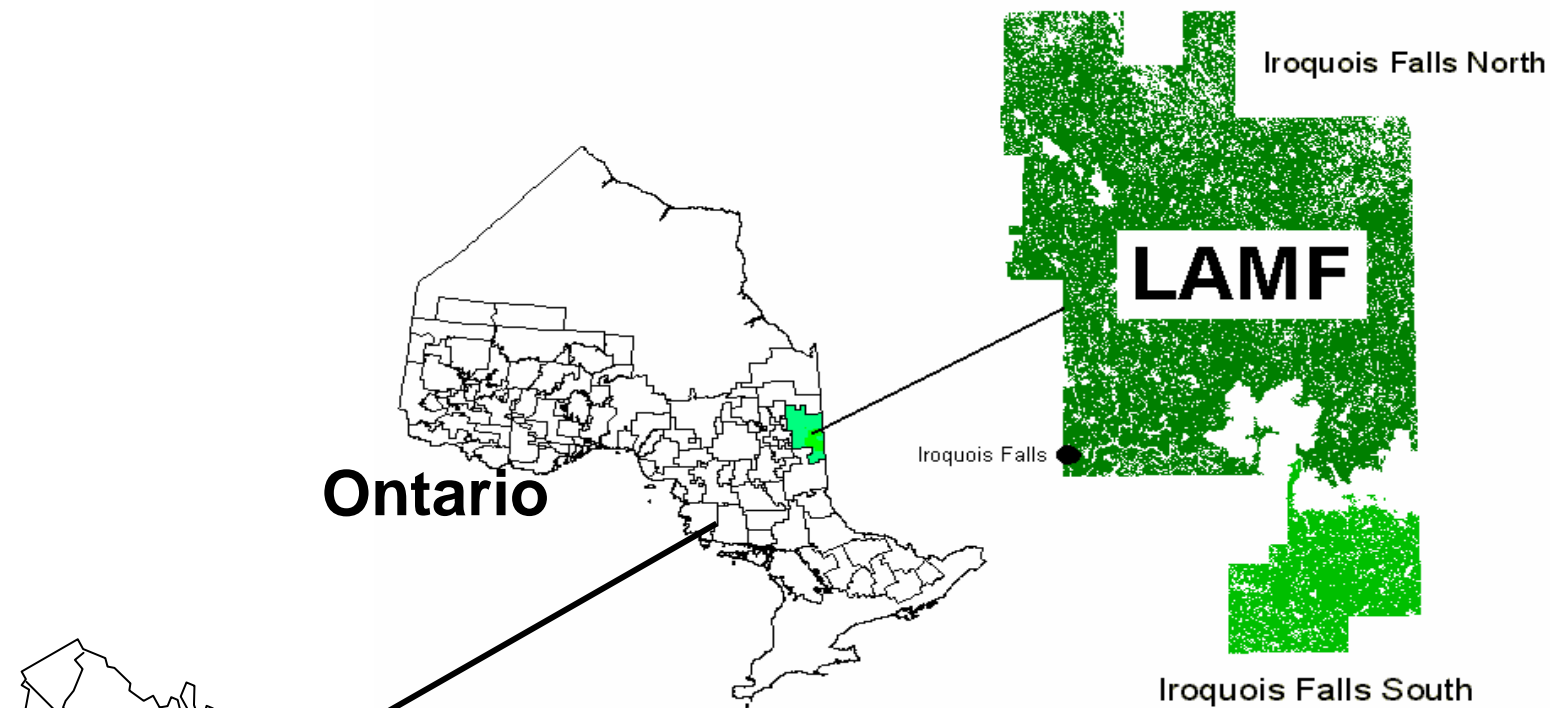
$\pm 10\%$

$\pm 15\%$

$\pm 20\%$

$\pm 25\%$

# Study area: Lake Abitibi Model Forest



**Canada**

**Ontario**

**LAMF**

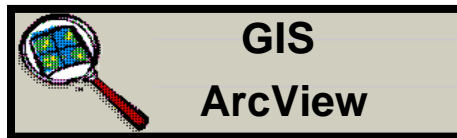
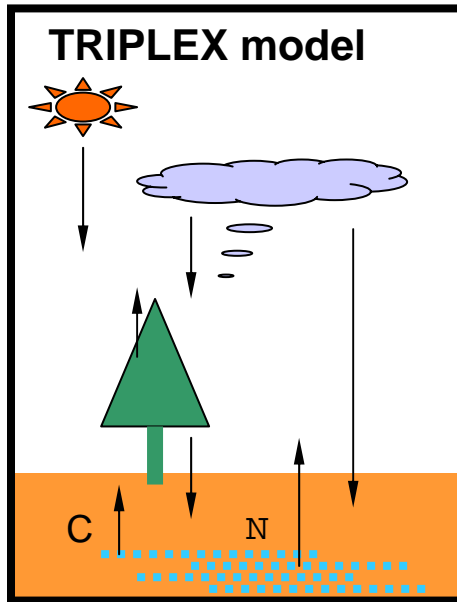
**Longitude and Latitude : -80.7, 48.8**

**Temperature: 1.2°C**

**Precipitation: 814.8 mm**

# Method

## Simulation Model



Spatial  
Distribution

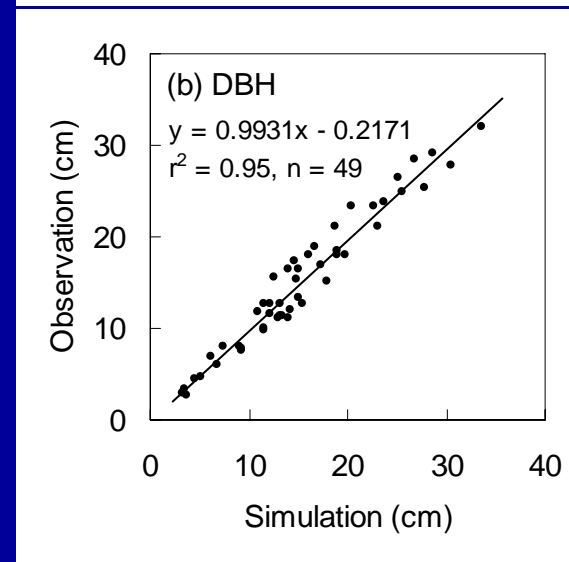
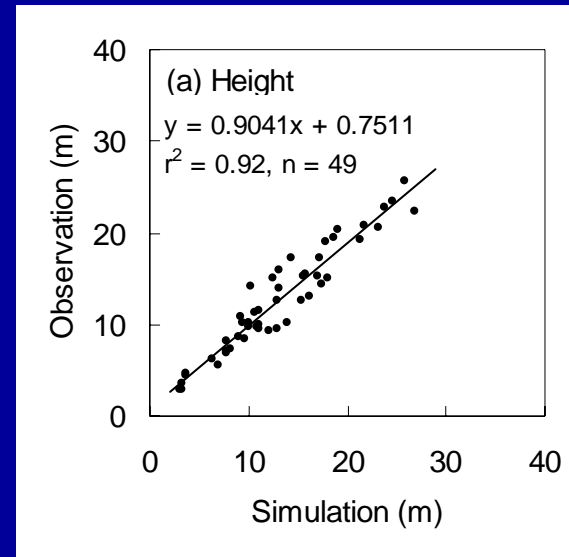
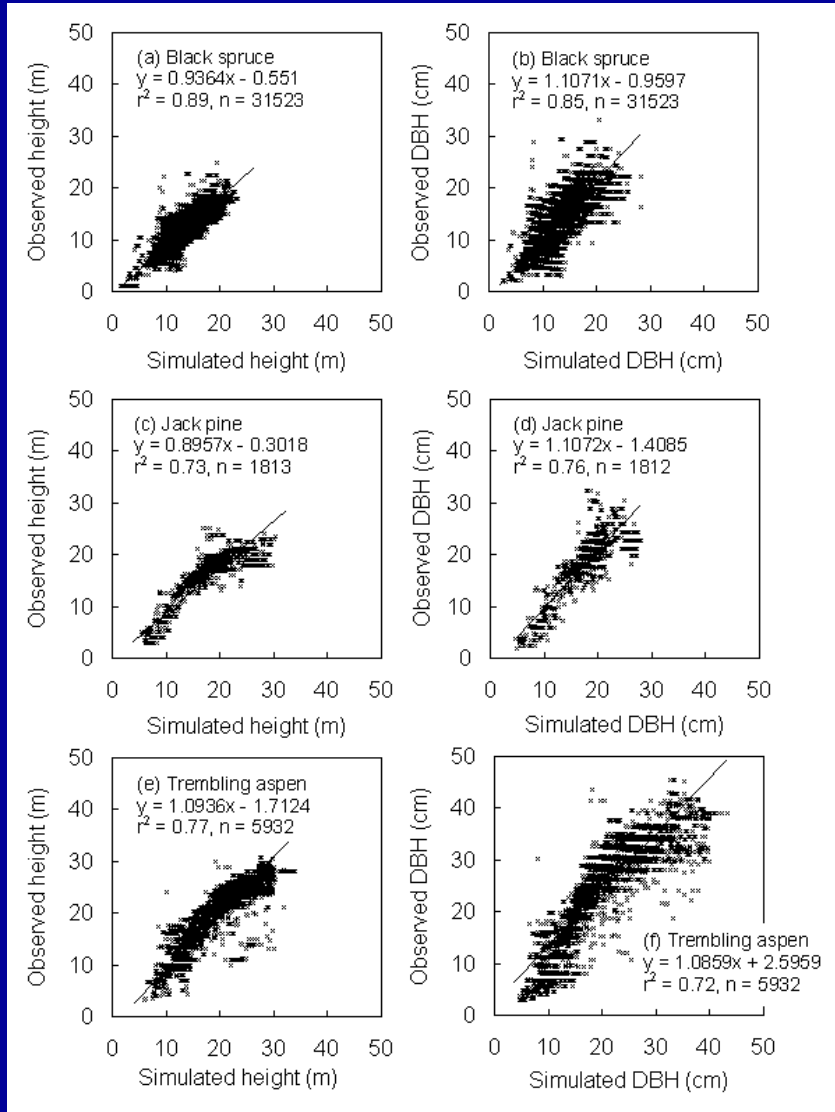
## Outputs

### Dynamics

Biomass  
NPP  
Soil C & N  
DBH  
Height  
Volume  
.....



# Model validation

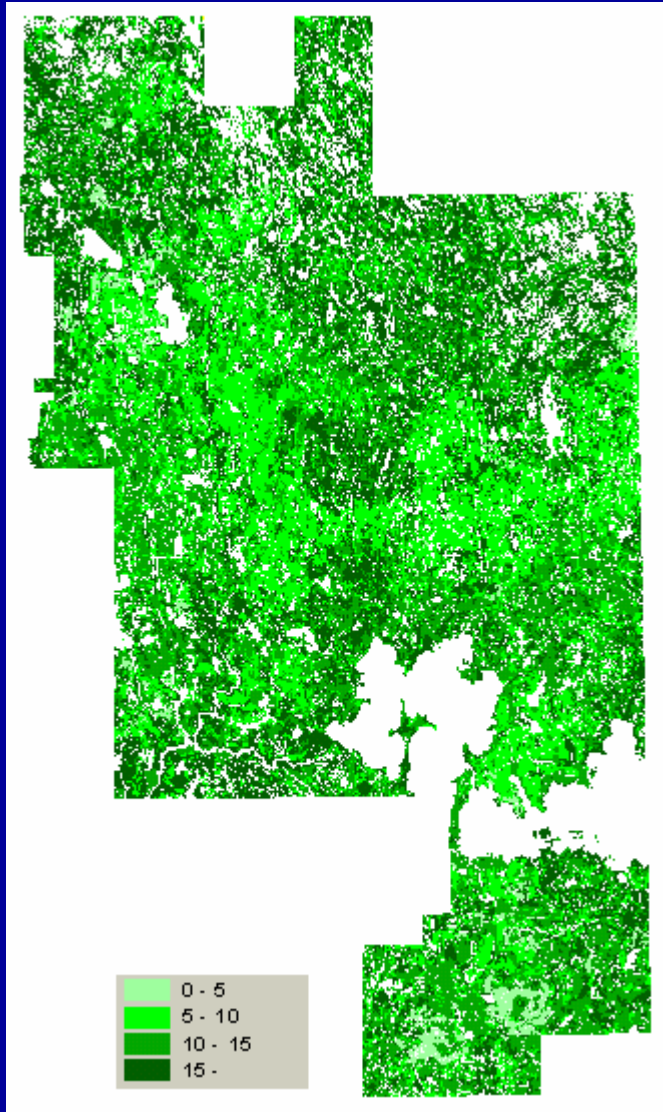


32 black spruce,  
9 jack pine,  
8 trembling aspen  
plots  
(measured in 1995)

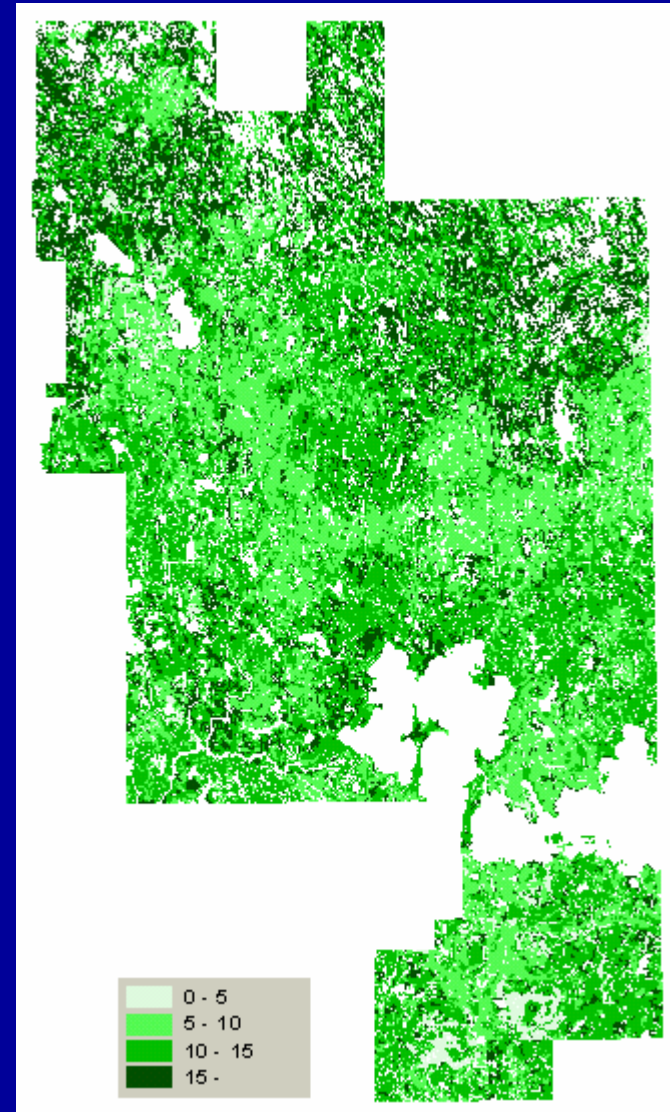
TRIPLEX vs. Forest Inventory

TRIPLEX vs. PSP

Total Height (m)

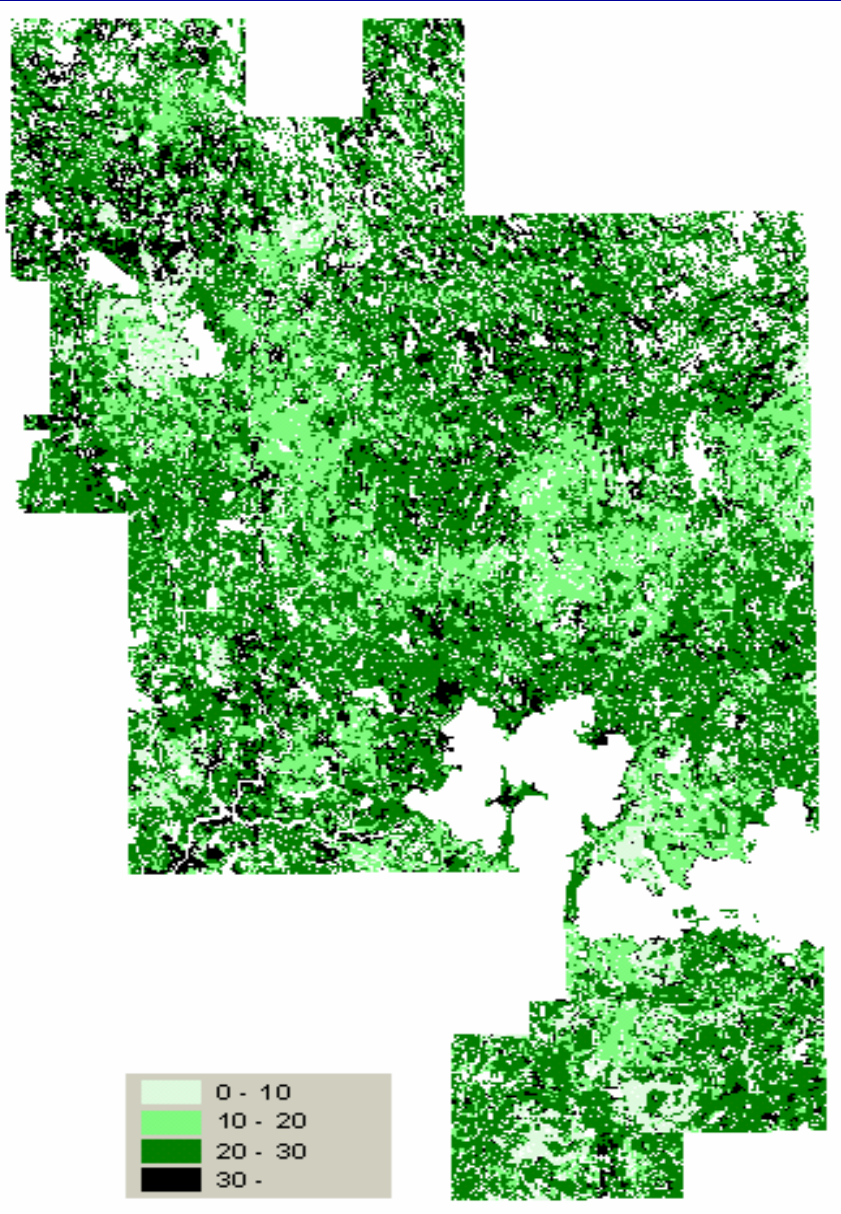


DBH (cm)



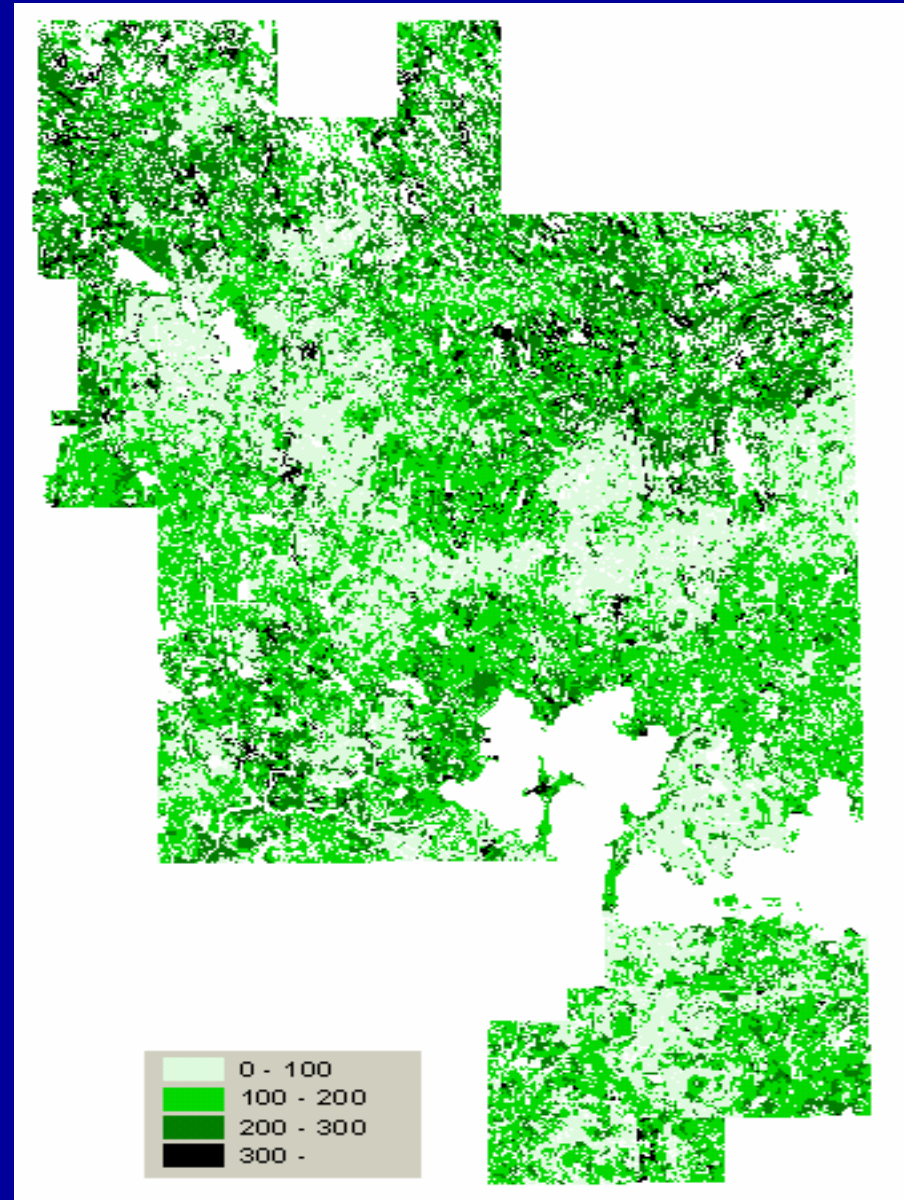
2000

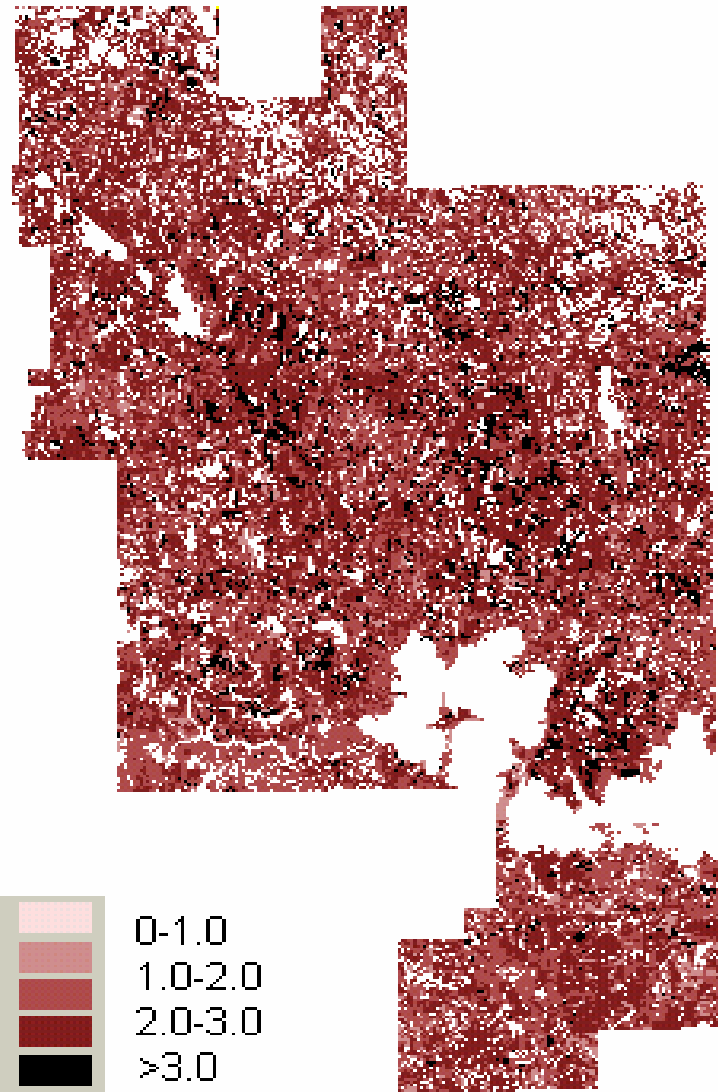
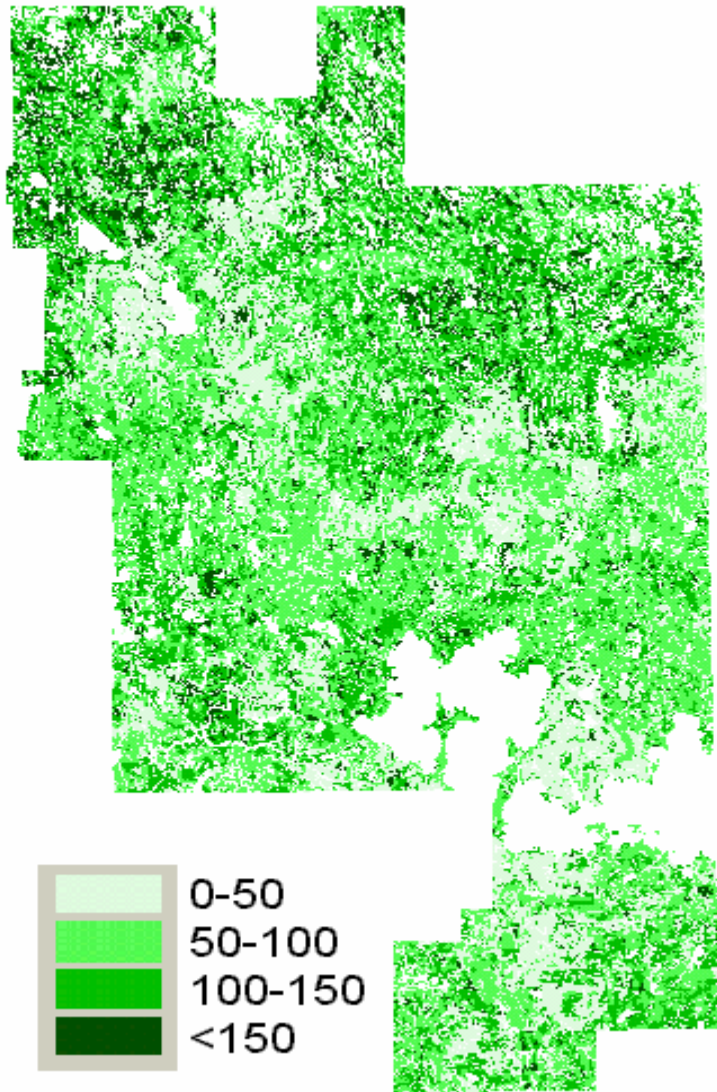
## Simulated Basal Area (m<sup>2</sup>/ha)



2000

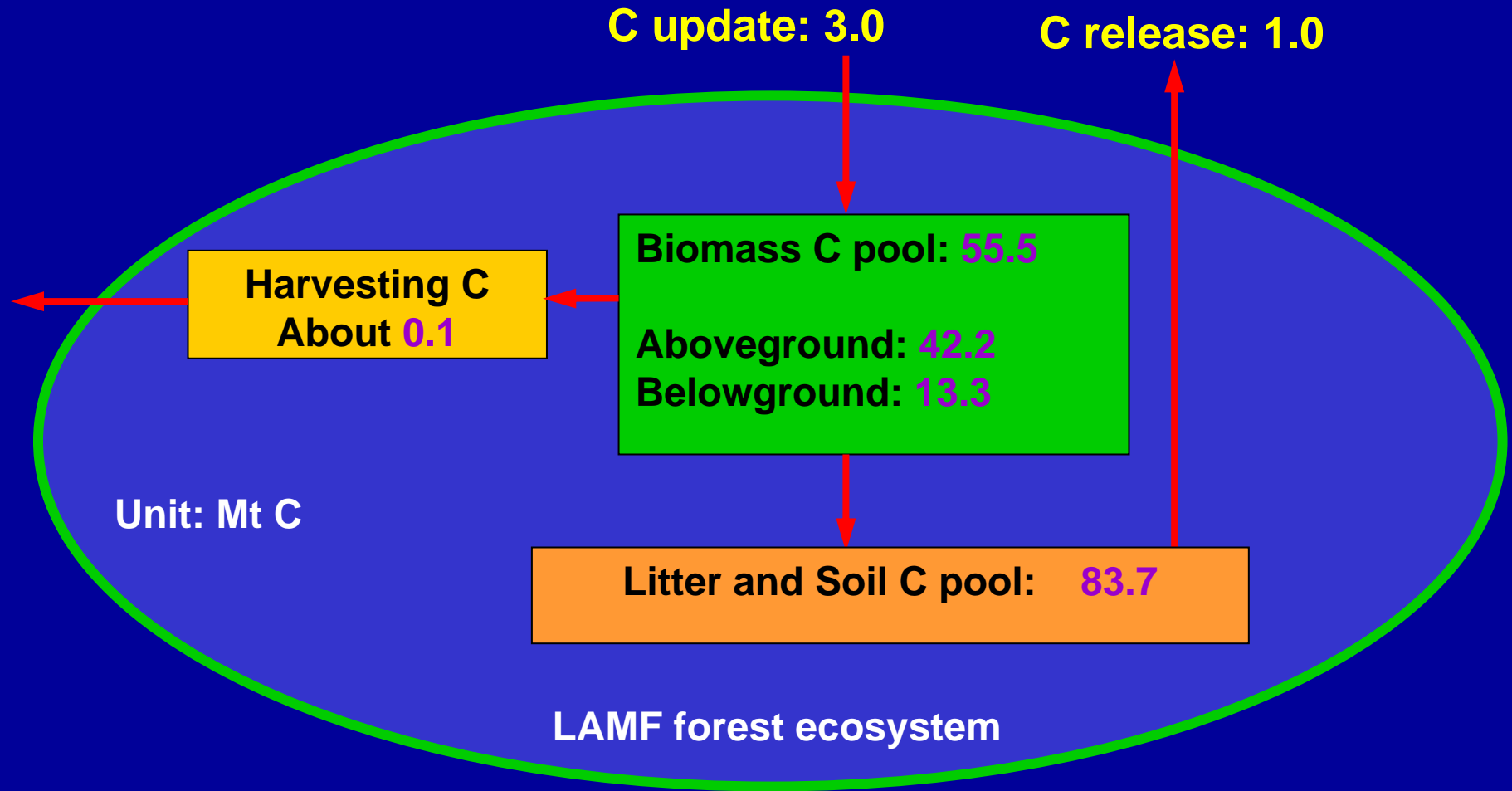
## Simulated Total Volume (m<sup>3</sup>/ha)





**Simulated Biomass ( $t\ ha^{-1}$ )  
in 2000**

**Simulated NPP ( $tC\ ha^{-1}yr^{-1}$ )  
in 2000**

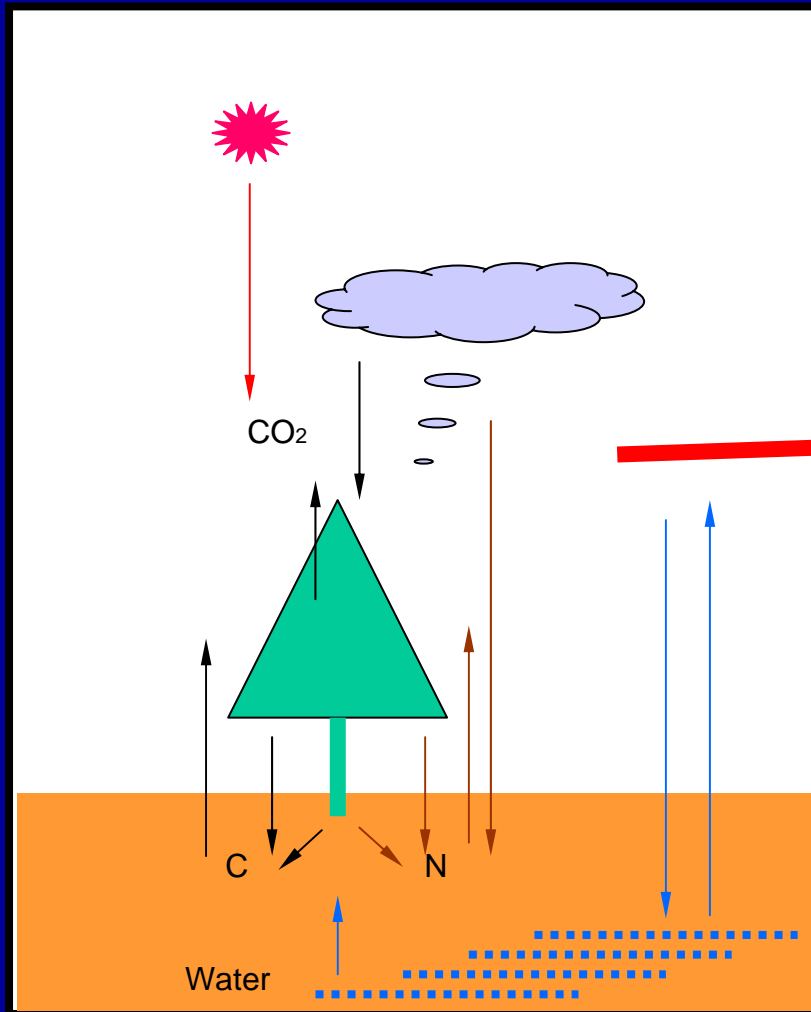


## C budget of LAMF forest ecosystem in 2000:

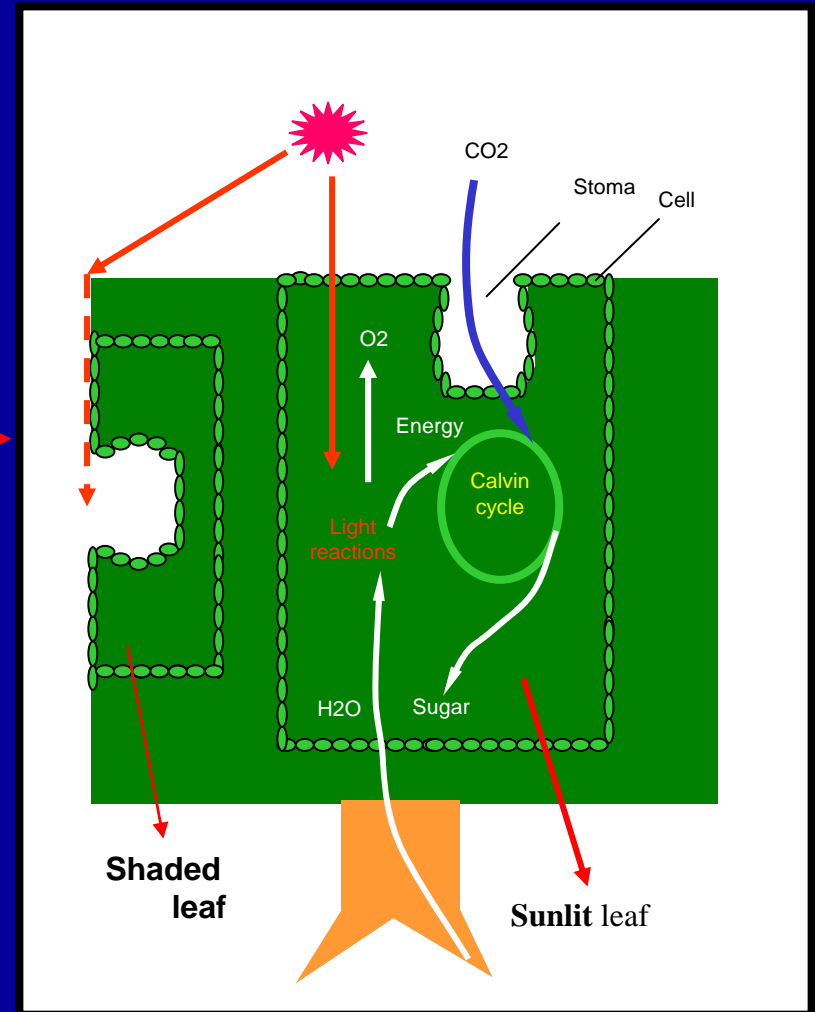
Net carbon balance (NCB) = 2.0 Mt C

# New TRIPLEX-Flux Model Development

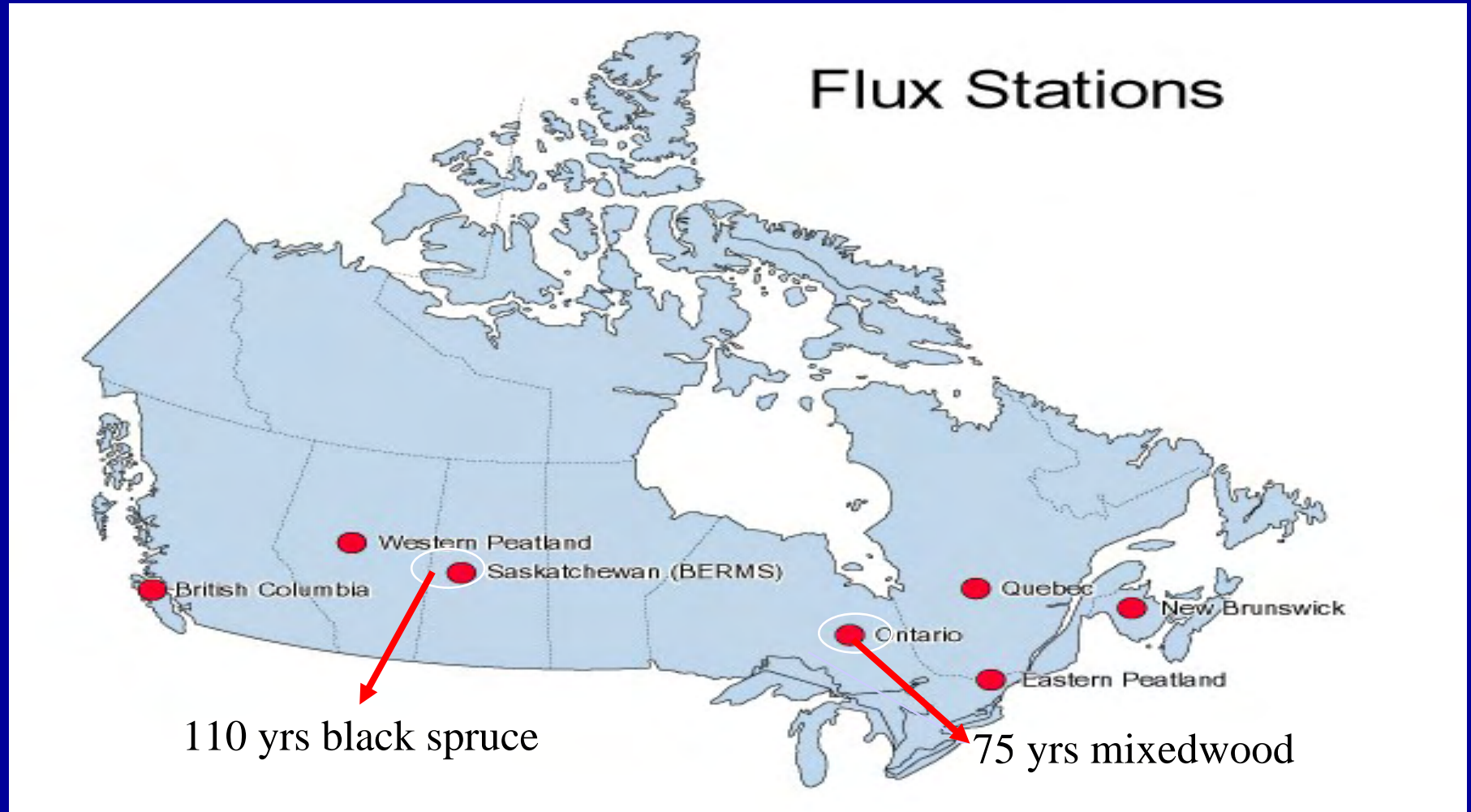
TRIPLEX1.0 (big leaf, monthly)



TRIPLEX-Flux (two leaves, daily)

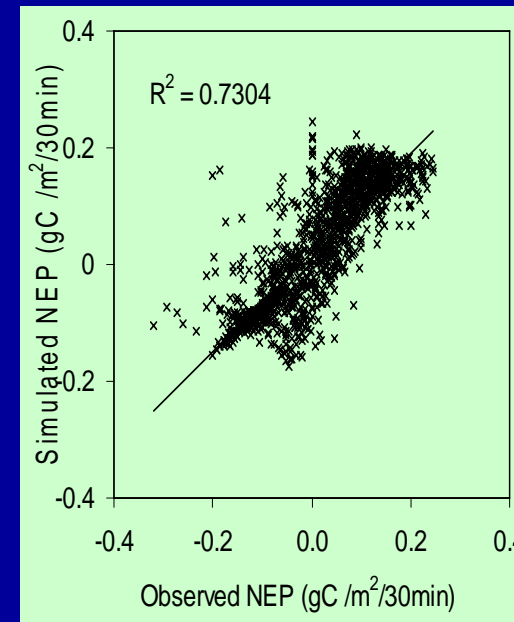
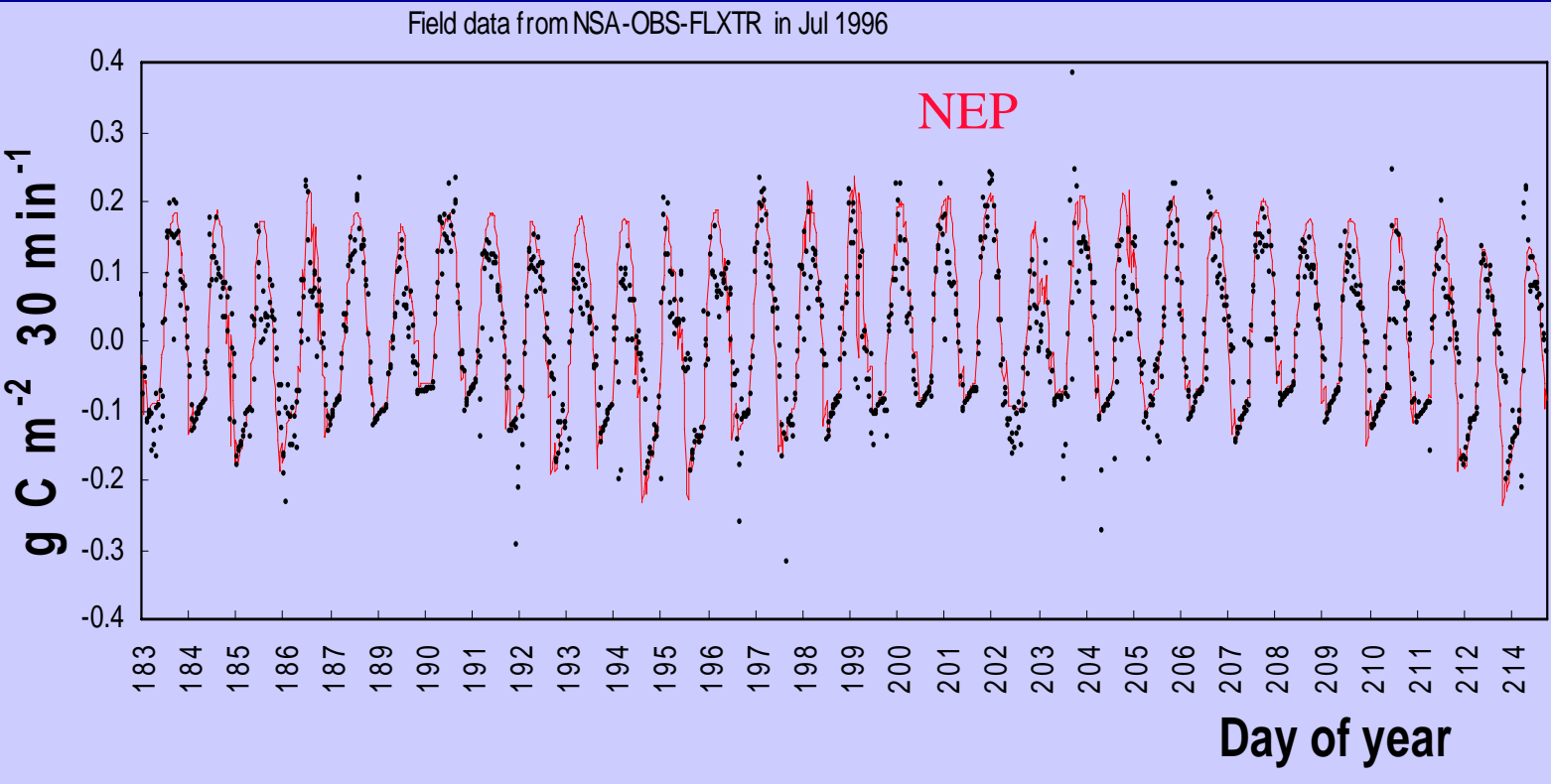


# Model Testing for 2 Flux tower sites



(Fluxnet-Canada)

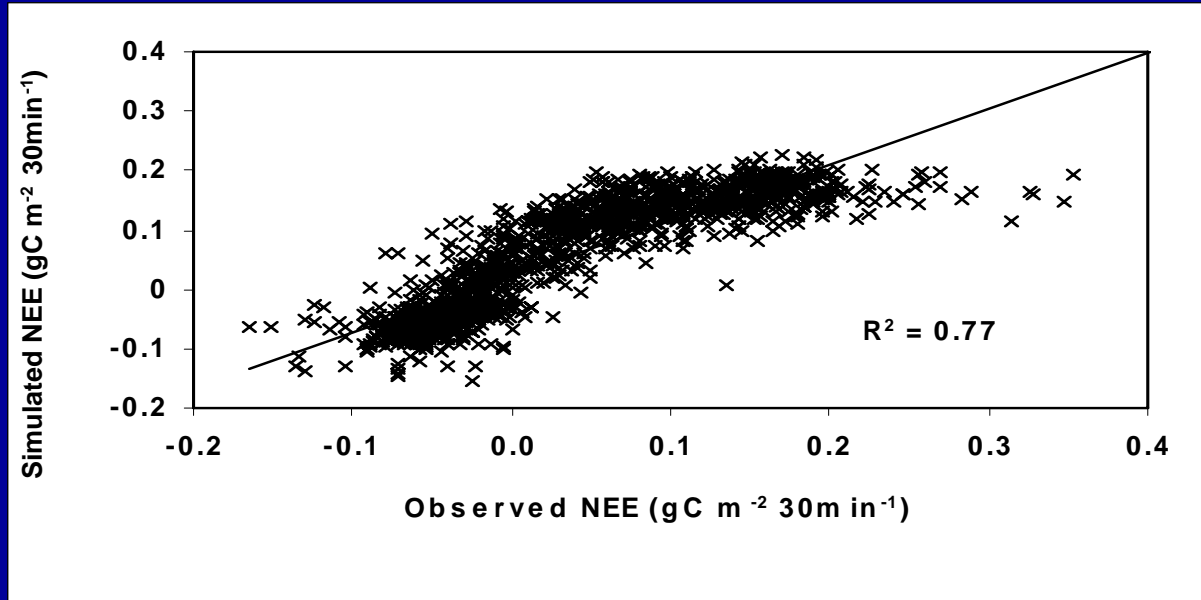
# Model Validation – OBS Flux Tower



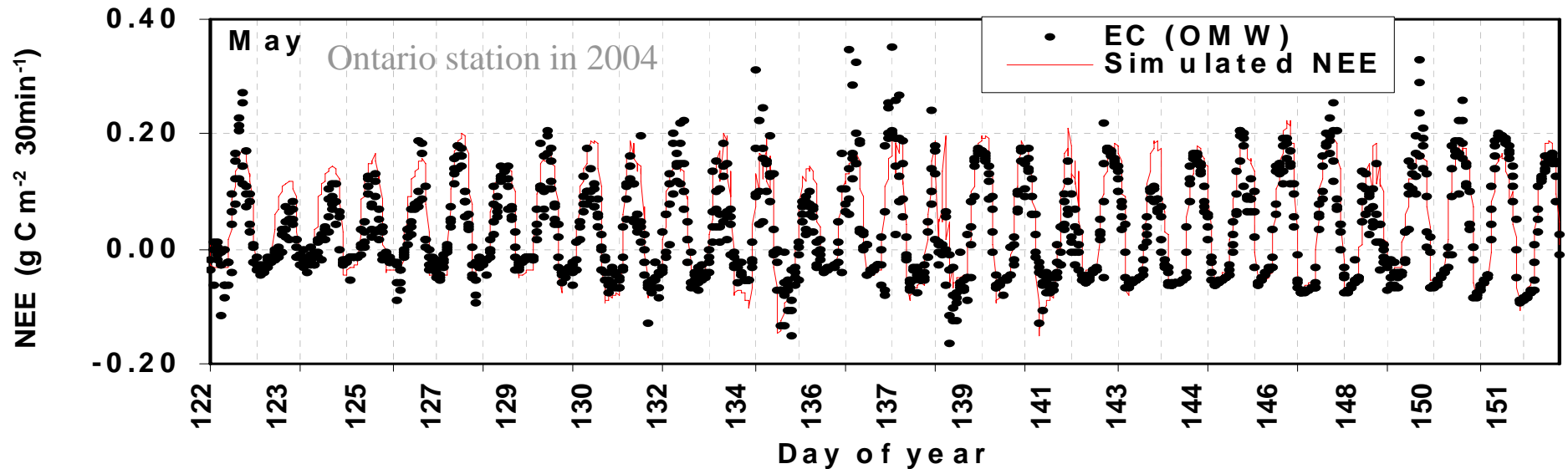
Daily Simulation using TRIPLEX-flux

(Zhou et al, 2008)

# Boreal Mixedwood Site (Ontario)



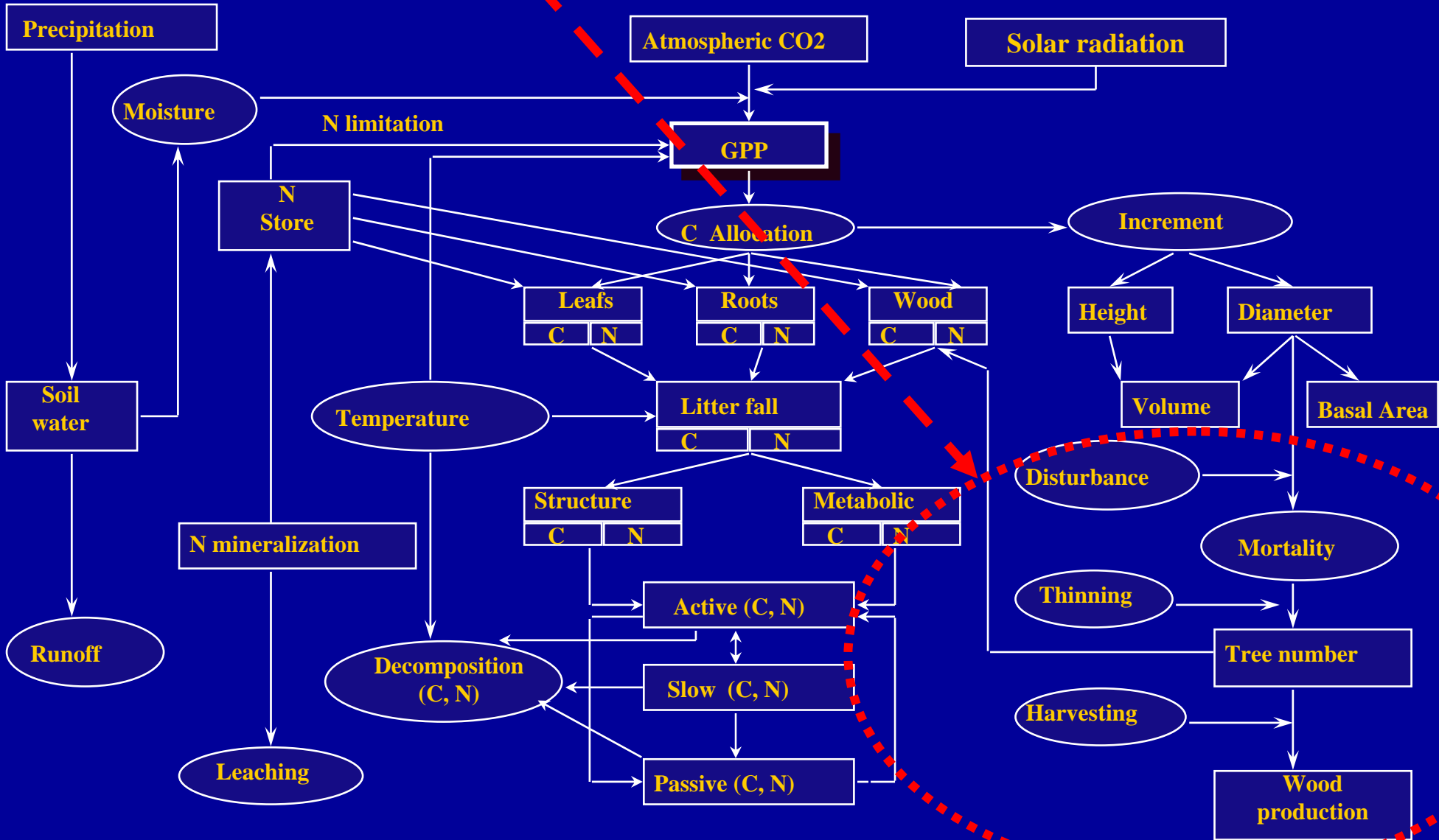
(Sun et al., 2008)



# Challenges for TRIPLEX Development

- **Continued testing of the model's ability to simulate NPP, belowground biomass, soil C, N and water (BOREAS sites as well as Canada-Fluxnet)**
- **Developing submodels (TRIPLEX-Fire, TRIPLEX-DOC, TRIPLEX-harvest) to include the effects of CO<sub>2</sub> fertilization, ecosystem disturbances (fire, harvesting, insects, disease), land use, and forest management planning**
- **Scaling up — linking TRIPLEX with remote sensing and GIS (estimated PAR, LAI through NDVI, etc...)**

# TRIPLEX-Management



# Looking for new MS, or Ph.D. or PDF students

Please contact: Dr. Changhui Peng

by E-mail: [peng.changhui@uqam.ca](mailto:peng.changhui@uqam.ca)

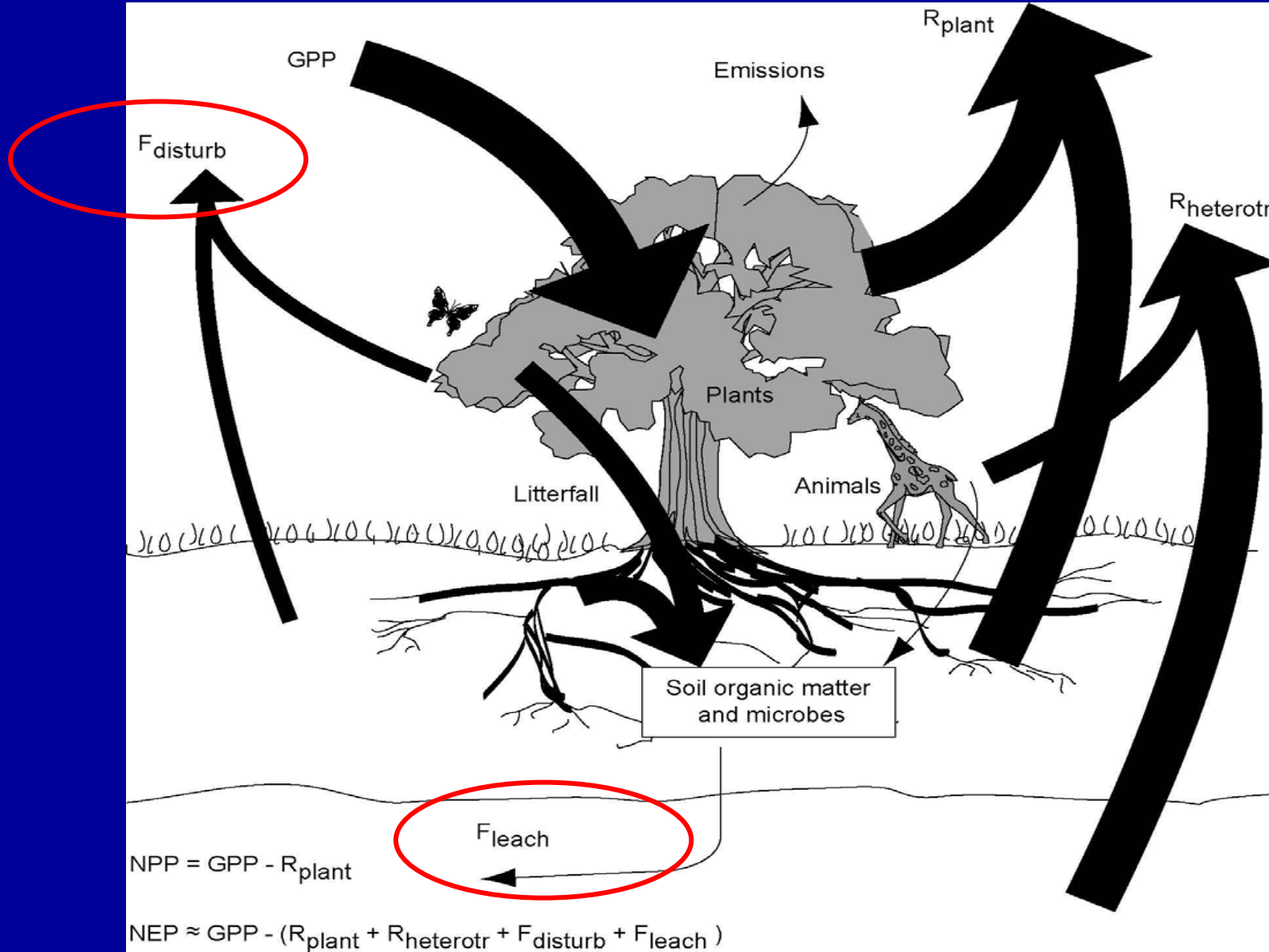
## **2008 NSERC Strategic Grant:**

**Modelling the Impacts of Thinning on the Structure, Biomass, Carbon Sequestration and Economics Value of Jack Pine Stands ( Changhui Peng and Tony Zhang)**

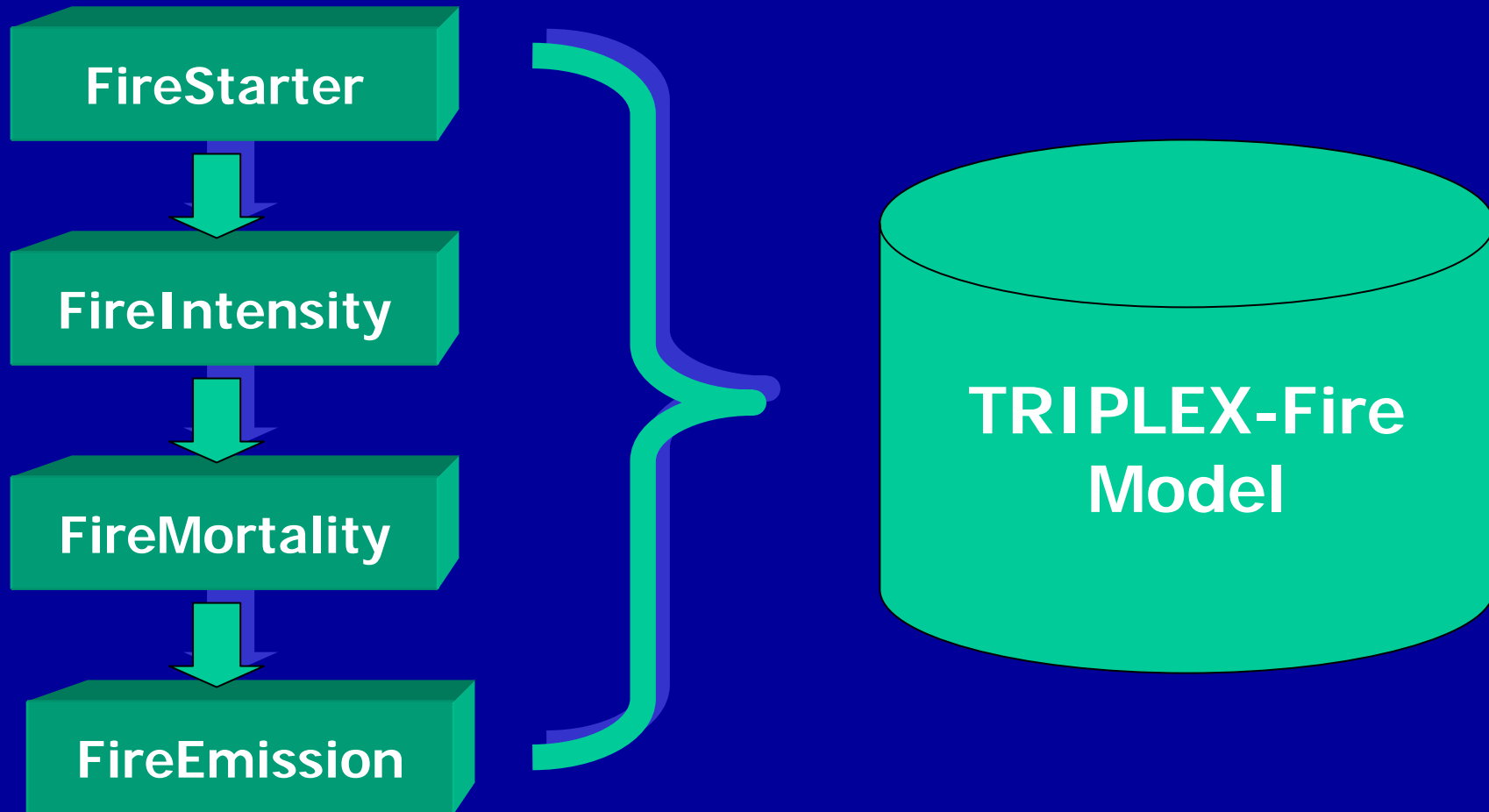
## **2008 FQRNT en Group:**

**Effets interactifs des changements climatiques et des feux de forêts sur la croissance forestière, la succession, et le bilan de carbone dans les écosystèmes de la forêt boréale du Québec ( C. Peng, J.P. Blanchet, Y. Bergeron)**

# Uncertainty

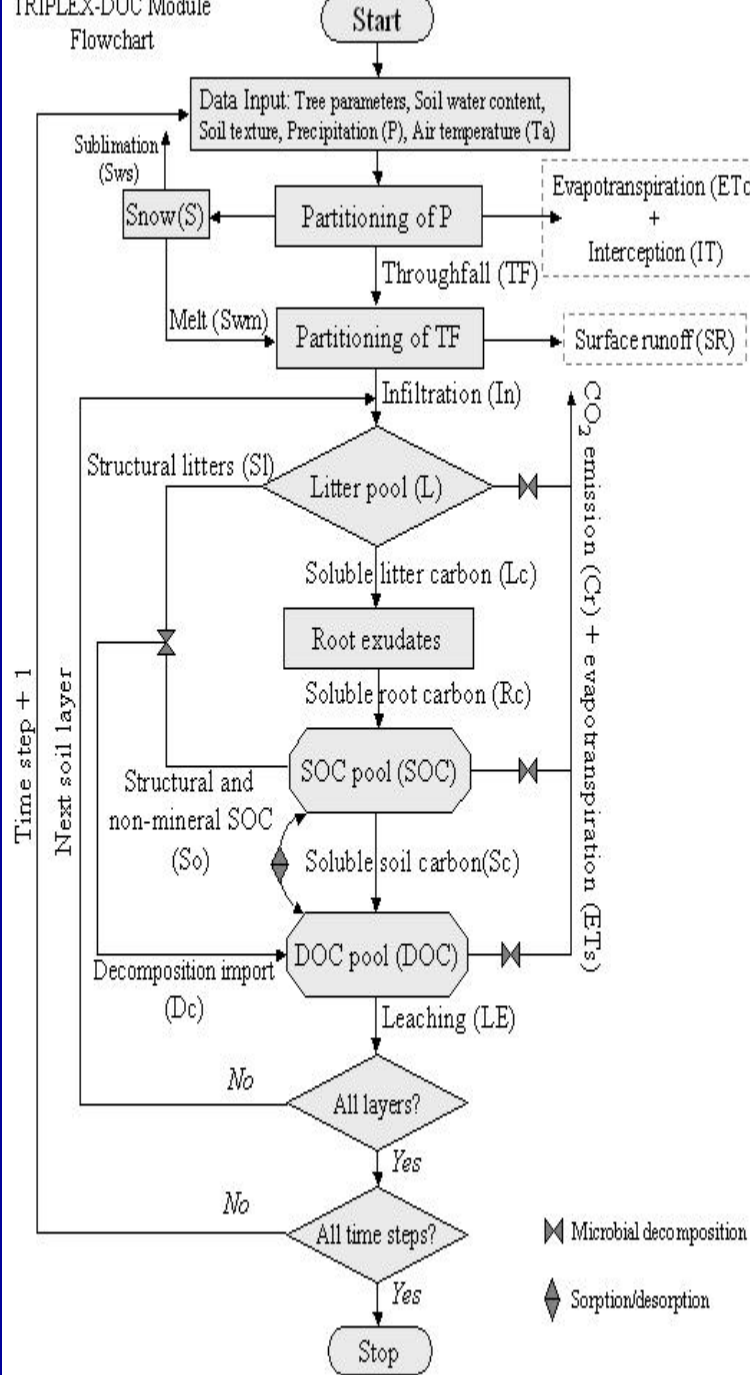
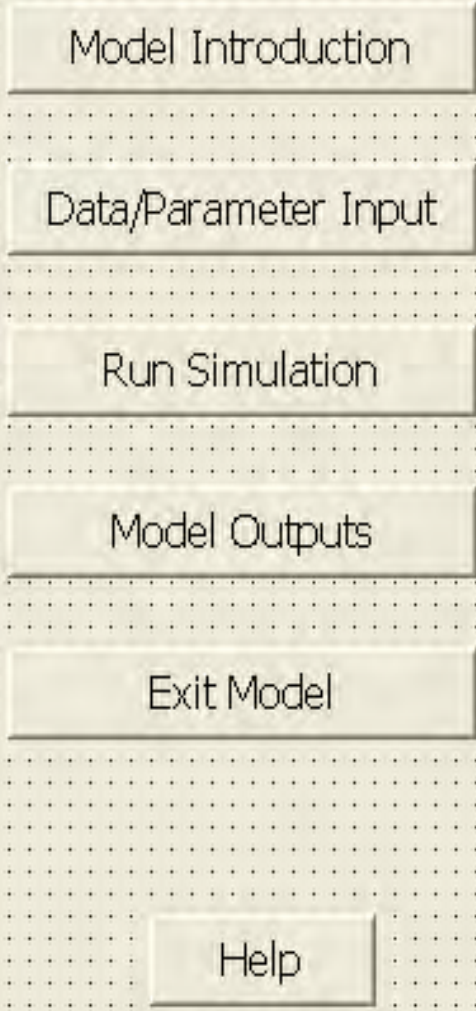


# Fire Module Developments





# Forest Dissolved Organic Carbon Simulator



# Acknowledgements

- **Canada Research Chair Program**
- **Fluxnet-Canada Research Network (FCRN)**
- **Canadian Foundation for Climate and Atmospheric Science (CFCAS)**
- **Natural Science and Engineering Research Council (NSERC)**

*Drs. Qinglai Dang, Jinxun Liu, Xiaolu Zhou, UQAM/ Lakehead University*

*Mrs. Susan Parton, Lake Abitibi Model Forest*

# Challenge: Validation

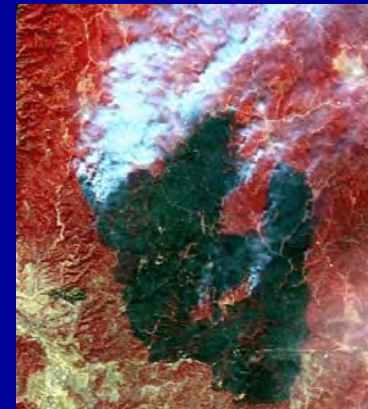
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**Validation** is testing a model to see how well it predicts. (How well does the model capture the structure, controls, and dynamics of a real forest ecosystem).

- **First questions is: what variable do we want to validate (test)?**
- **The second question is finding adequate data.**

# Data for Validating Forest Model

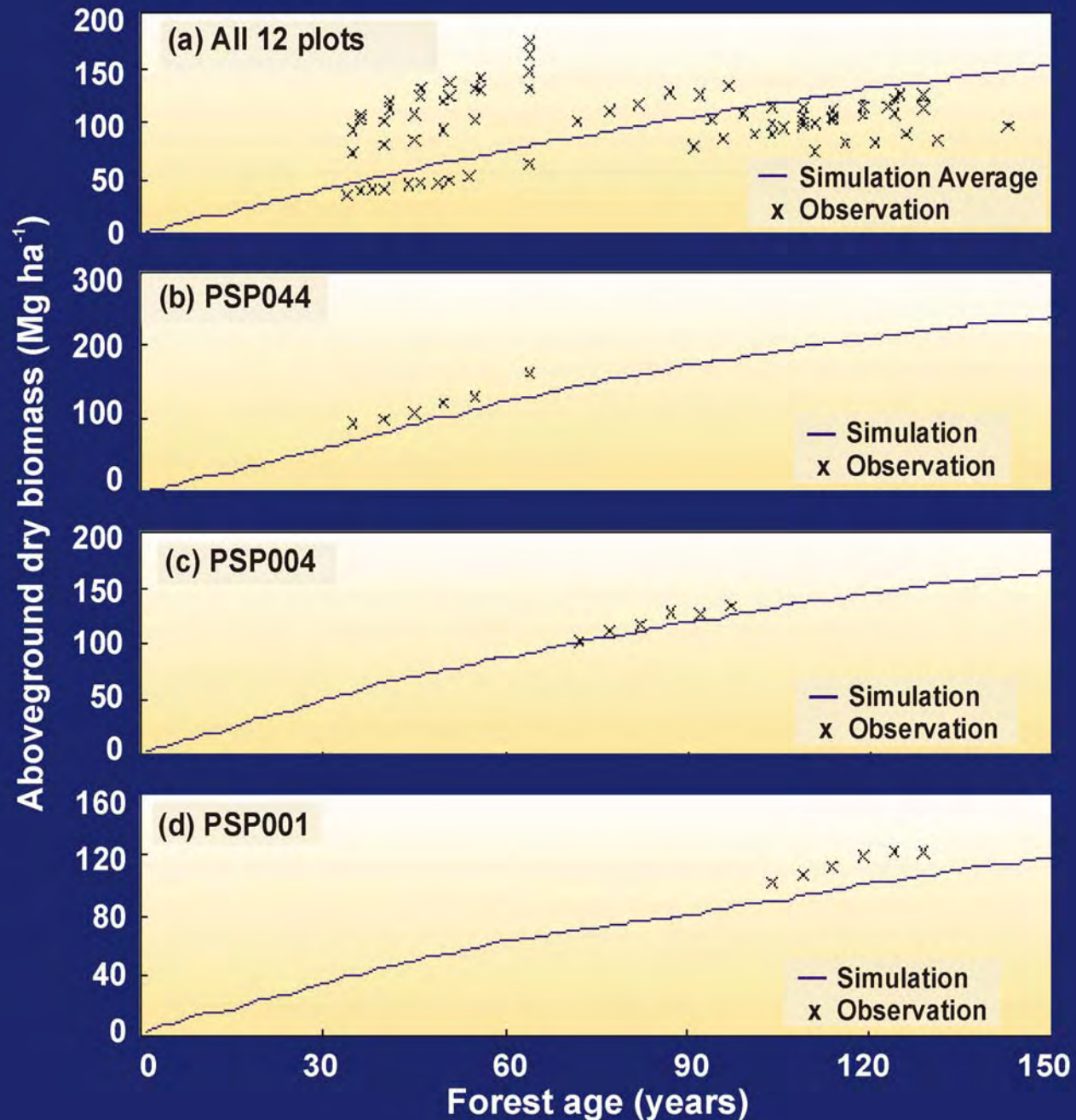
- Greenhouse or experimental data
- *Tree growth plots (PSP, TSP)*
- Forest inventory
- Flux tower (CO<sub>2</sub>, NPP, NEP etc..)
- Remote Sensing (NDVI-NPP)
- Paleocological data (tree-ring, pollen)

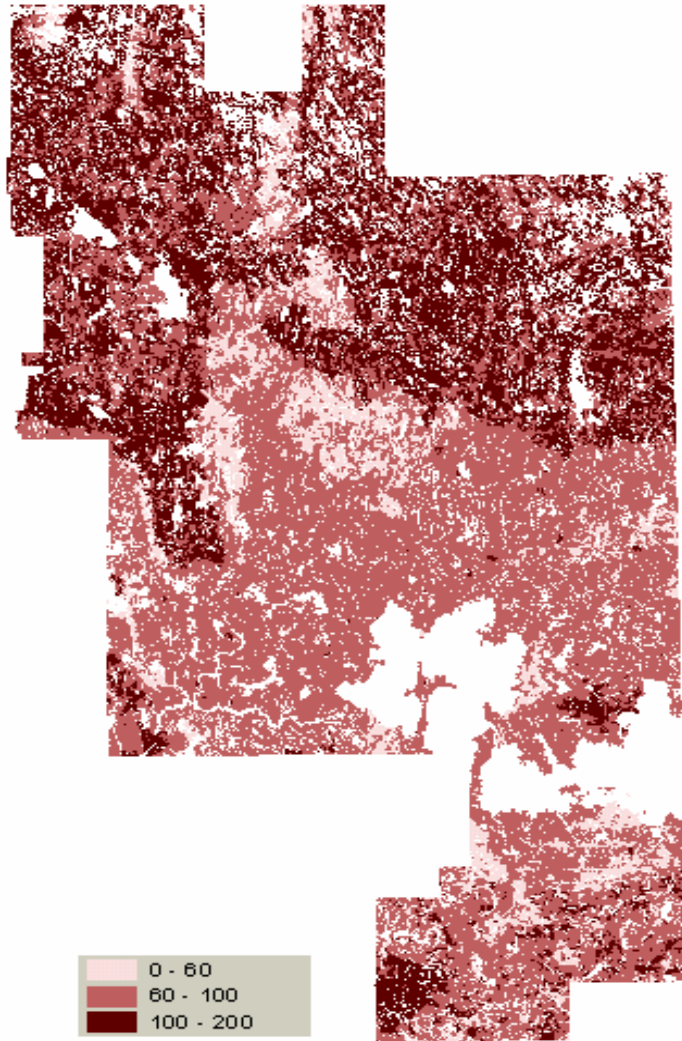


Click here to learn  
about tree rings  
& to try crossdating  
for yourself.



# Comparison of Averaged Simulations and Observations - Aboveground Biomass (Hegyi, 1972)

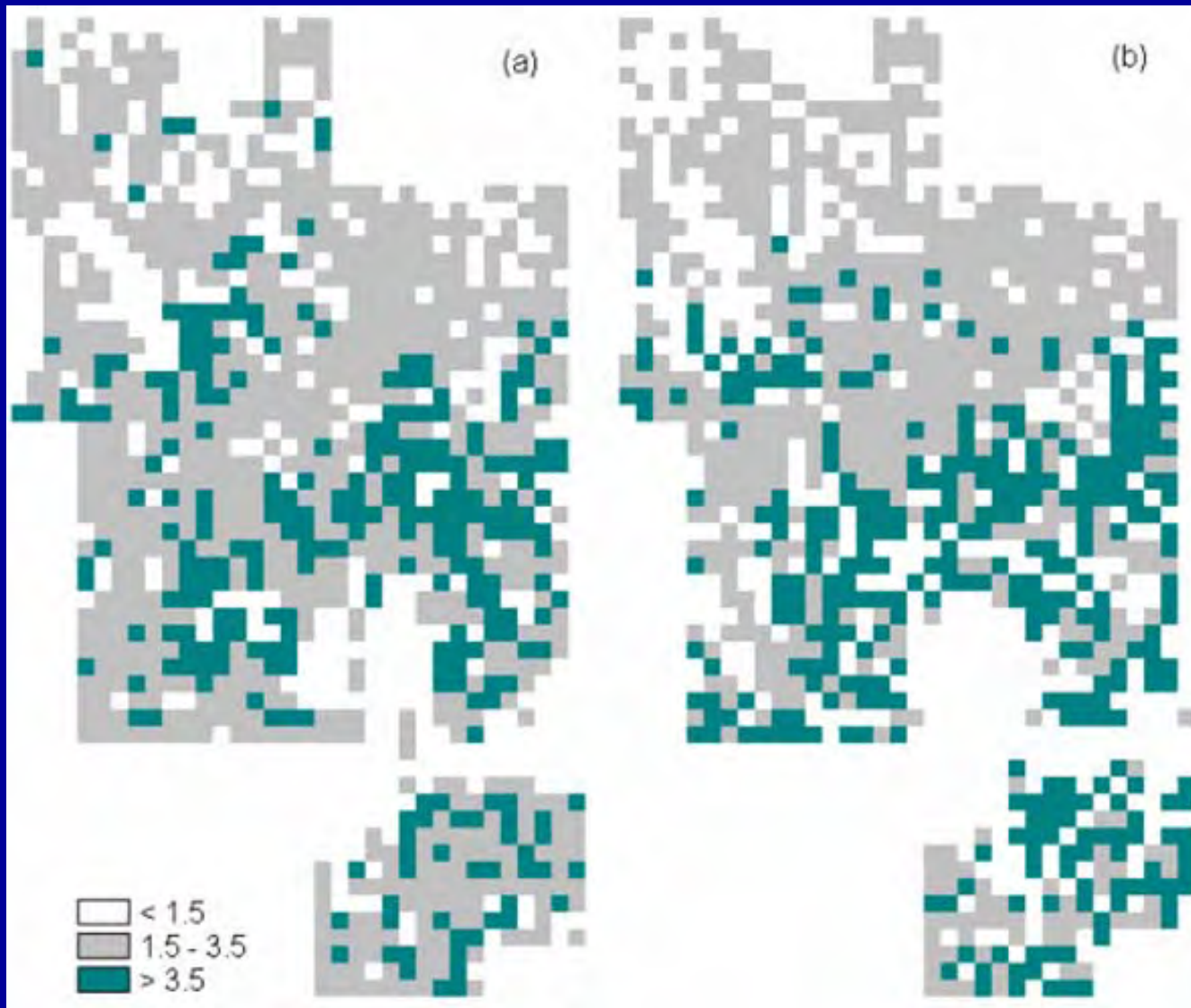




**Simulated Soil carbon (tC ha<sup>-1</sup>)  
in 2000**

**Soil texture**

# NPP Spatial Distribution at Landscape Level



(a) TRIPLEX  
(Zhou et al, 2005)

(b) Remote Sensing  
(Liu et al, 2002)

*Fig. 4 The comparison between NPP ( $t\ C\ ha^{-1}\ yr^{-1}$ ) simulations at landscape (a) and remote sensing (b) levels for the LAMF in 1995. (a) was based on the TRIPLEX model simulation for 1995 (averaged  $3.28\ t\ C\ ha^{-1}\ yr^{-1}$ ,  $SD=0.79$ ), and (b) was converted using spatial data from Liu et al. (2002) for 1994 (averaged  $3.08\ t\ C\ ha^{-1}\ yr^{-1}$ ,  $SD=1.15$ ). The grid size is  $3\times 3\ km$ .*

**Kappa Statistic ( $k$ ) = 0.55**

**Good agreement if  $0.55 < K < 0.7$**

# Problems of Applying Process Models in Forest Management

**Most Process models (FOEST-BGC, PnET, TEM, CENTURY etc..) are**

- **not designed to predict stand characteristic (such as BA, DBH, H and annual mortality), and thus the outputs are not directly useful in management planning**
- **too complex and require a large amount of information beyond what is readily available to forest managers**
- **lacking a user-friendly modeling interface and their documentation is insufficient, making them difficult for forest managers to use**

**(Peng et al., 2002, *Ecological Modelling*)**

# One Solution: Hybrid Models

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“ ...The development of hybrid models, which combine physiological process models with more traditional growth and yield models, will be specially useful for integrating physiological processes with larger scale stand dynamics processes...”

*(Martin, Johnsen, and White, 2001. Forest Science, 47: 21-28)*