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Optimization of wood production in bioenergy plantations: Through the use of adequate plant material in terms of resource use efficiencies

Julien Toillon, Bénédicte Rollin, Erwin Dallé, Jean-Charles Bastien, Franck F. Brignolas, Nicolas Marron

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Optimization of wood production in bioenergy plantations

Through the use of adequate plant material
in terms of resource use efficiencies

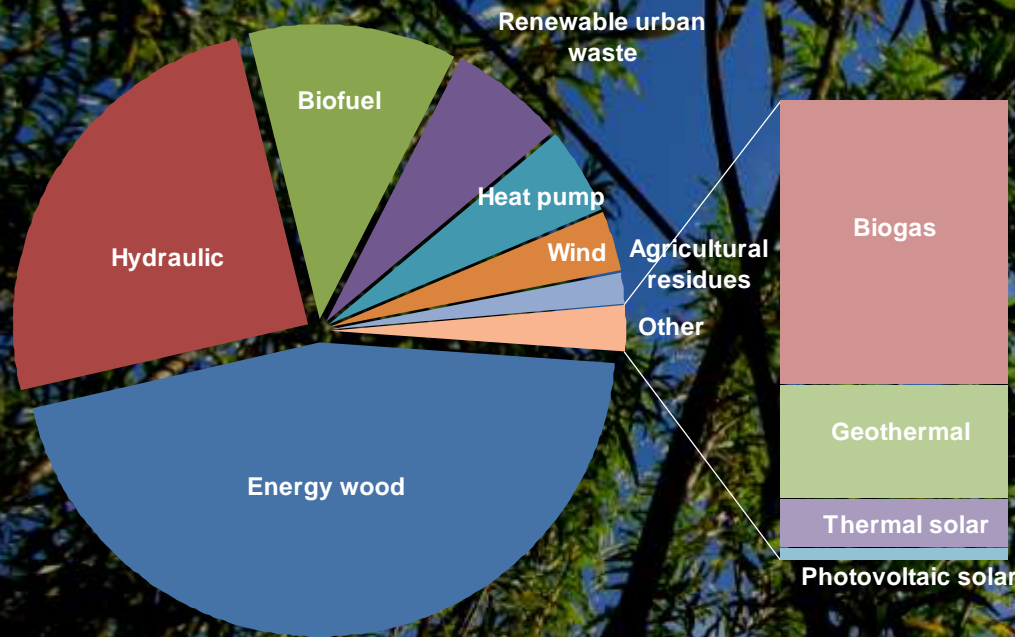
Julien TOILLON, Bénédicte ROLLIN, Erwin DALLÉ
Jean-Charles BASTIEN, Franck BRIGNOLAS & Nicolas MARRON

Why?

How?

Where?

What?



European directive : 20% of produced energy have to be renewable

→ 7.9% in France in 2009

→ 45% from wood (forest and SRC)

→ Need of 8 to 10 millions hectares to reach the objectives...

→ ... avoiding concurrence with food agriculture

Why?

How?

Where?

What?



European directive : 20% of produced energy have to be renewable

- 7.9% in France in 2009
- 45% from wood (forest and SRC)
- Need of 8 to 10 millions hectares to reach the objectives...
- ... avoiding concurrence with food agriculture
- Use of suboptimal lands
- Optimization of wood production while reducing inputs
- Use of plant material using efficiently water and nitrogen

Why?

How?

Where?

What?



Most frequently used tree species in Europe:

- Poplar
- Willow
- Eucalyptus
- Black locust (*Robinia*)

→ 1500 to 12 000 trees / ha

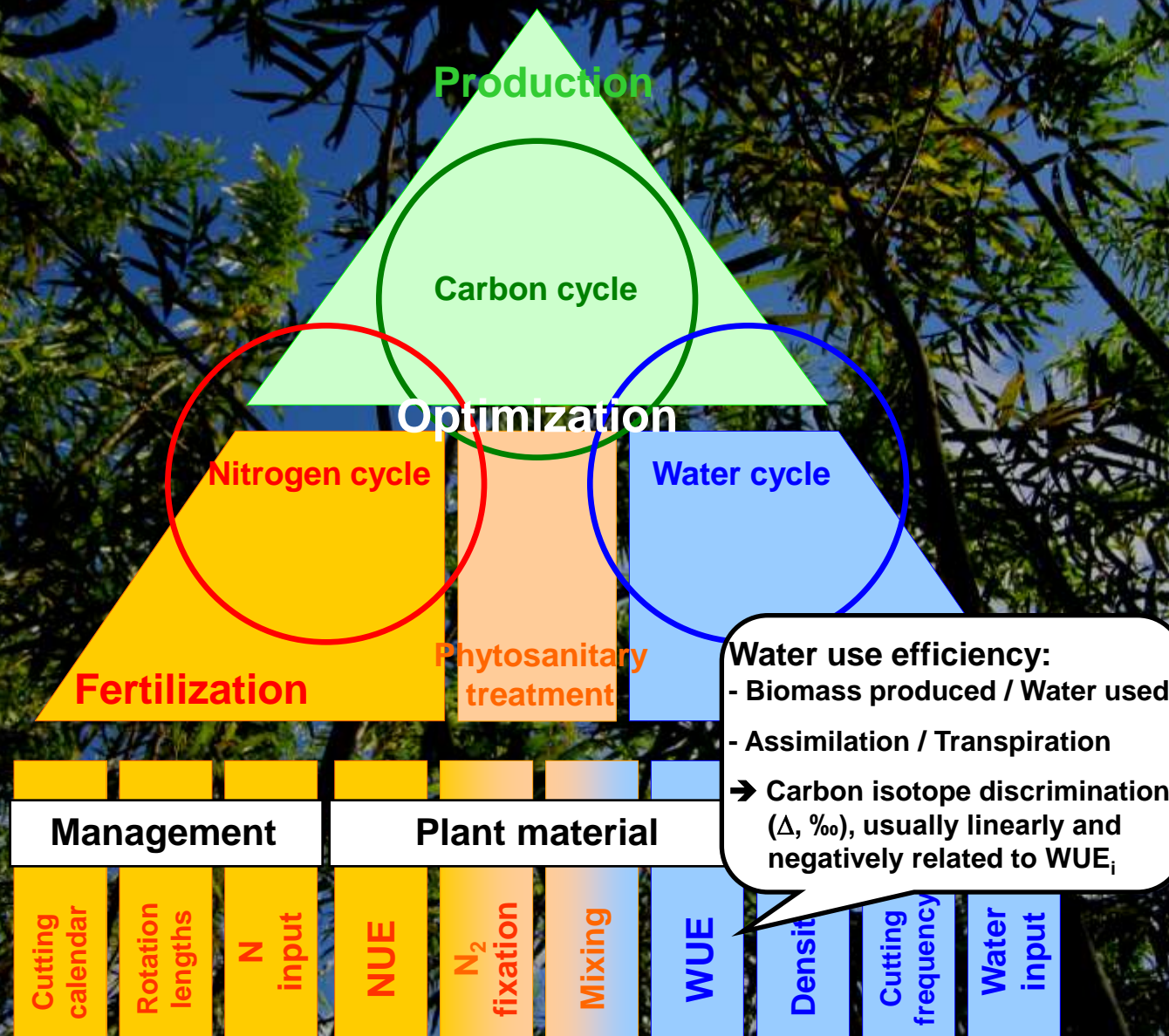
→ 2 to 8 year rotations

Why?

How?

Where?

What?



Water use efficiency:

- Biomass produced / Water used
- Assimilation / Transpiration

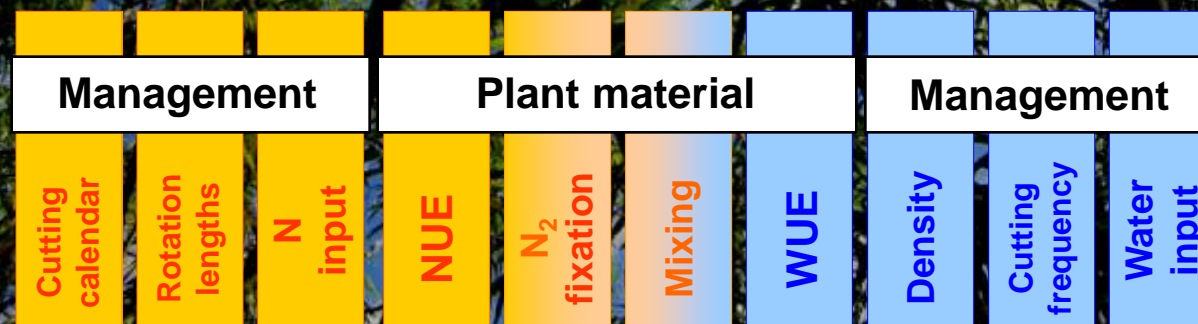
→ Carbon isotope discrimination (Δ , ‰), usually linearly and negatively related to WUE_i

Why?

How?

Where?

What?



Why?




How?

Where?

What?



Intens&Fix

- ERA-Net Bioenergy
- Franco-German cooperation
- "Cost optimization of short rotation crops adapted plantations"
- www.creff.eu
- French National Research Agency Call "ANR Bioenergies"
- Technical and scientific consortium
- "New concepts of sustainable energy crops with woody species"

				Cutting calendar	Management
				...	
				...	
				N ₂ fixation	Plant material
				Mixing	
X	X			WUE	Management
X	X			Density	
X				Cutting frequency	
X				Water input	

See poster

See poster

Why?

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What?

Association d'Initiatives Locales pour l'Énergie et l'Environnement

Institut National de la Recherche Agronomique

Forêt, Cellulose, Bois-construction, Ameublement

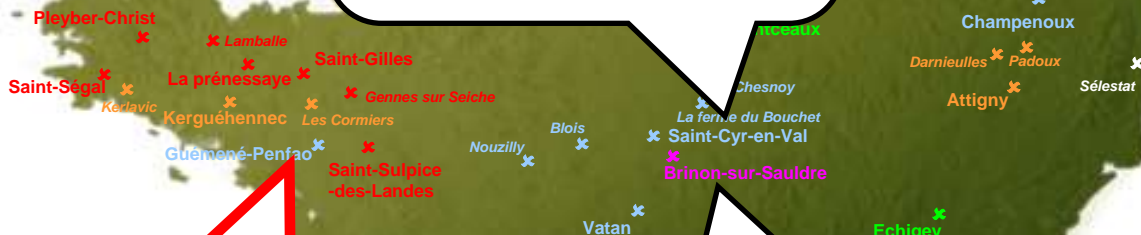
Chambres d'Agriculture

Institut pour le Développement Forestier

Laboratoire des Interactions Microorganismes Minéraux Matière Organique dans les Sols



Poplar clonal test (60 clones) + Willow clonal test (20 clones)



Robinia clonal test (30 clones) + 8 willow + 1 poplar clone



T°C : 16.7°C
Rainfall : 148 mm
OM : 39.5 g kg⁻¹
N : 1.7 g kg⁻¹

Brittany

8 willow clones



T°C : 17.0°C
Rainfall : 257 mm
OM : 9.9 g kg⁻¹
N : 0.6 g kg⁻¹

Centre

Poplar clonal test (60 clones) + 6 willow clones



T°C : 17.4°C
Rainfall : 382 mm
OM : 62.1 g kg⁻¹
N : 3.2 g kg⁻¹

Bourgogne

Growing conditions

Why?

How?

Where?

What?



Poplar
'Dorskamp'



Robinia
2 provenances



Willow
8 clones

The 3 species at the same site

Close Δ / WUE values for leaves and wood

Close Δ / WUE values for poplar and willow...

... but inferior for black locust

➔ Black locust more efficient to use water than poplar / willow?

➔ Or due to extreme conditions at this site in 2010?

More precisely for each species...

Robinia clonal test (30 clones)
+ 8 willow + 1 poplar clone



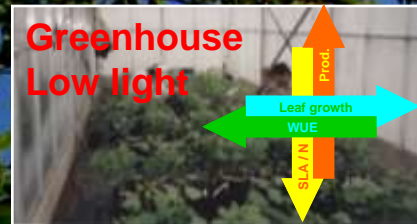
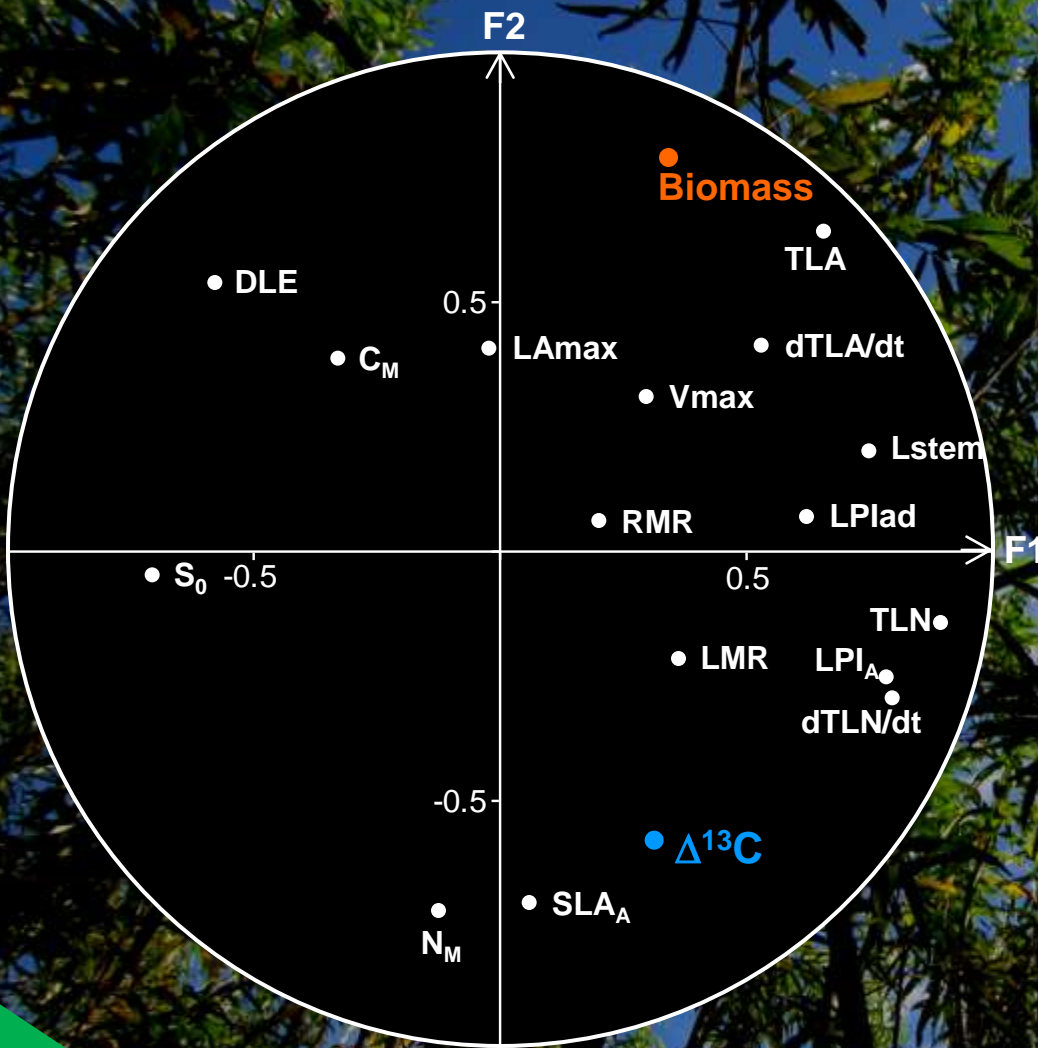
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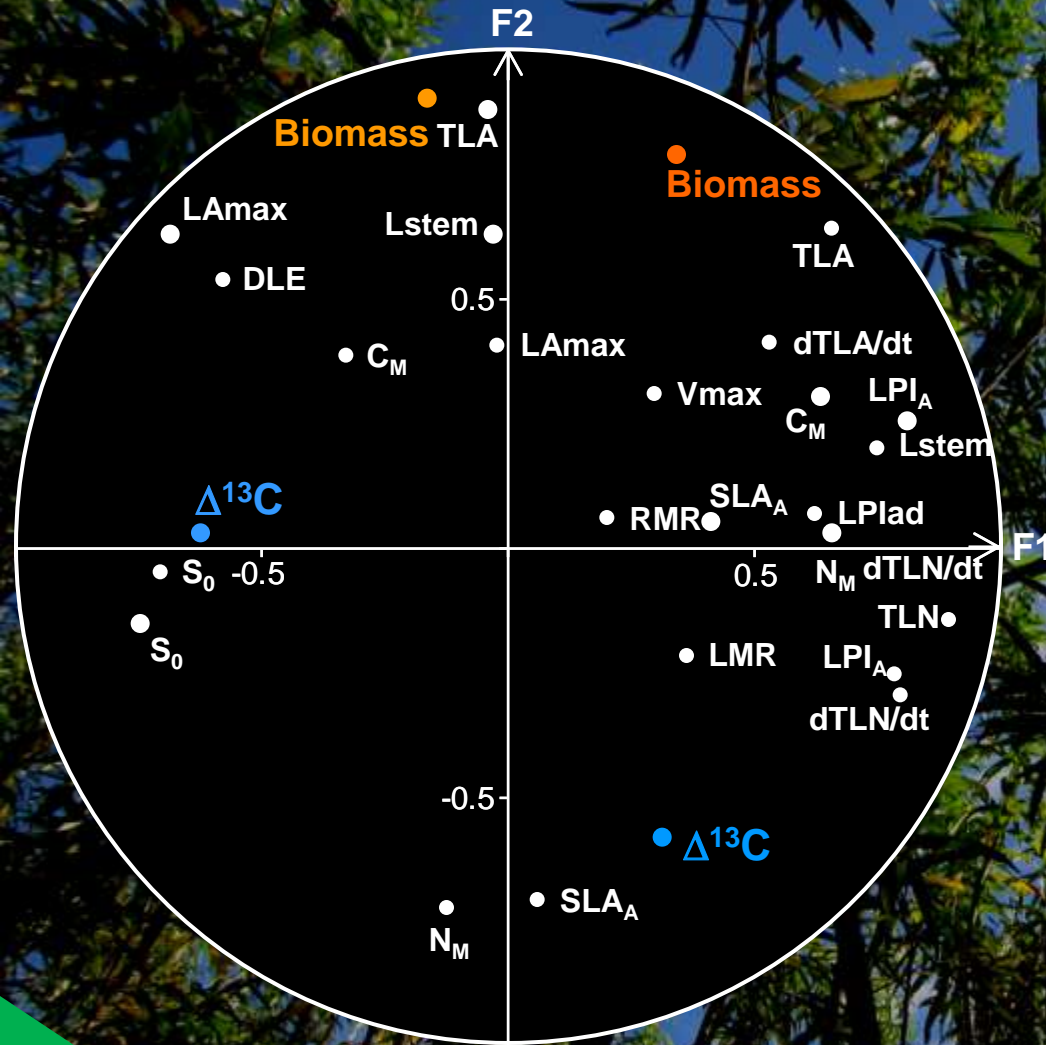
N : 1.7 g kg⁻¹

European poplar clones (Italy / Netherland / Belgium / France / Hungary)



Marron et al. 2005

European poplar clones (Italy / Netherland / Belgium / France / Hungary)

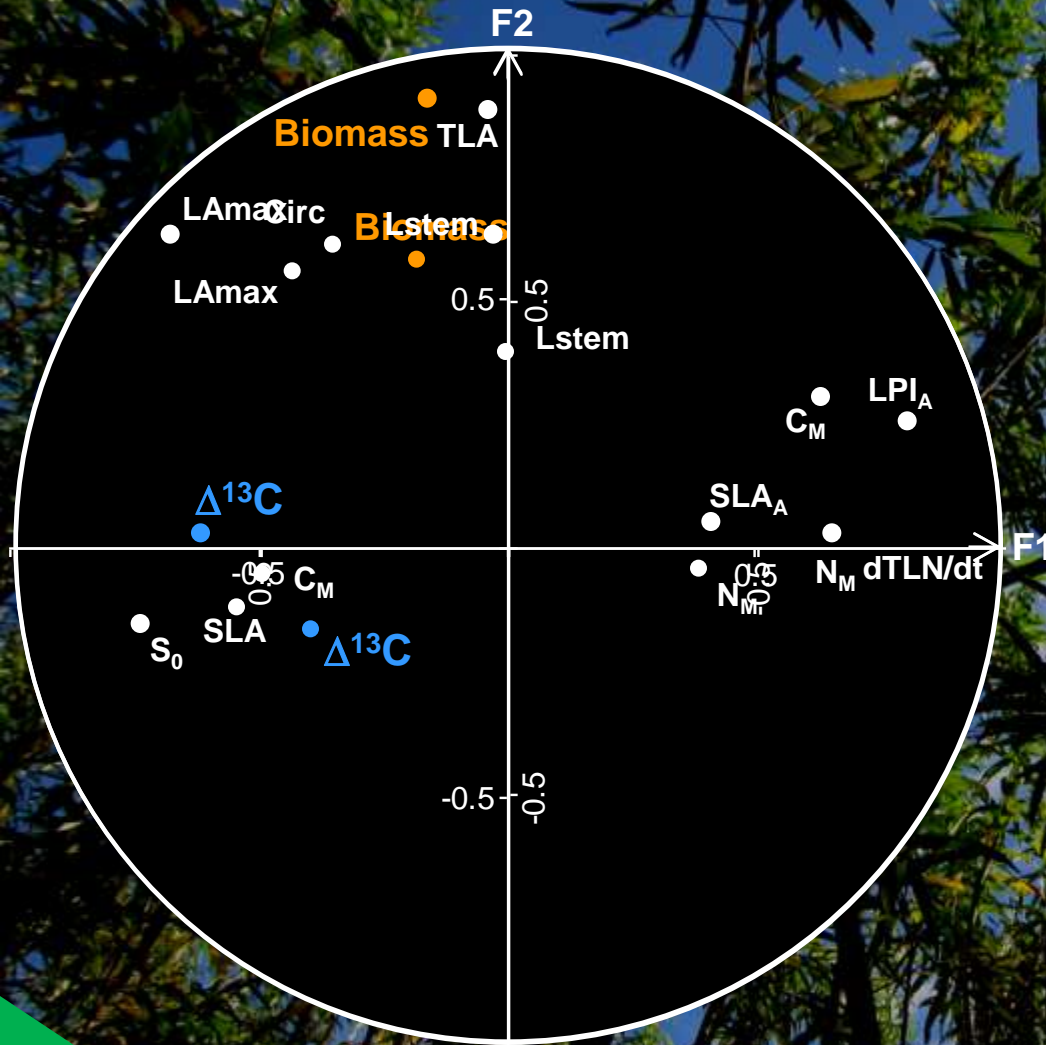


Marron et al. 2005



Monclus et al. 2005

European poplar clones (Italy / Netherland / Belgium / France / Hungary)



Marron et al. 2005



Monclus et al. 2005



Monclus et al. 2006

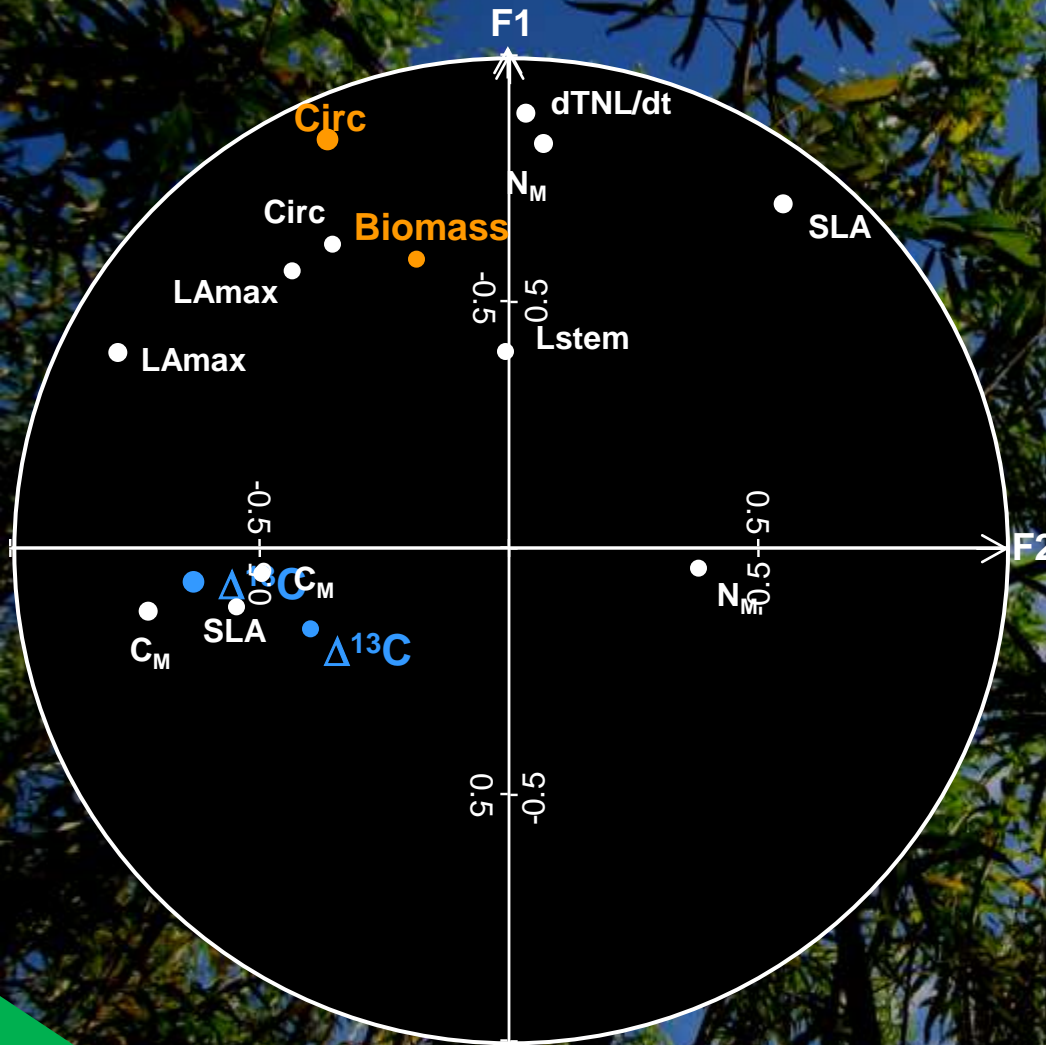
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European poplar clones (Belgian F1)



Marron *et al.* 2005



Monclus *et al.* 2005



Monclus *et al.* 2006



Marron and Ceulemans 2006

Dillen *et al.* 2011

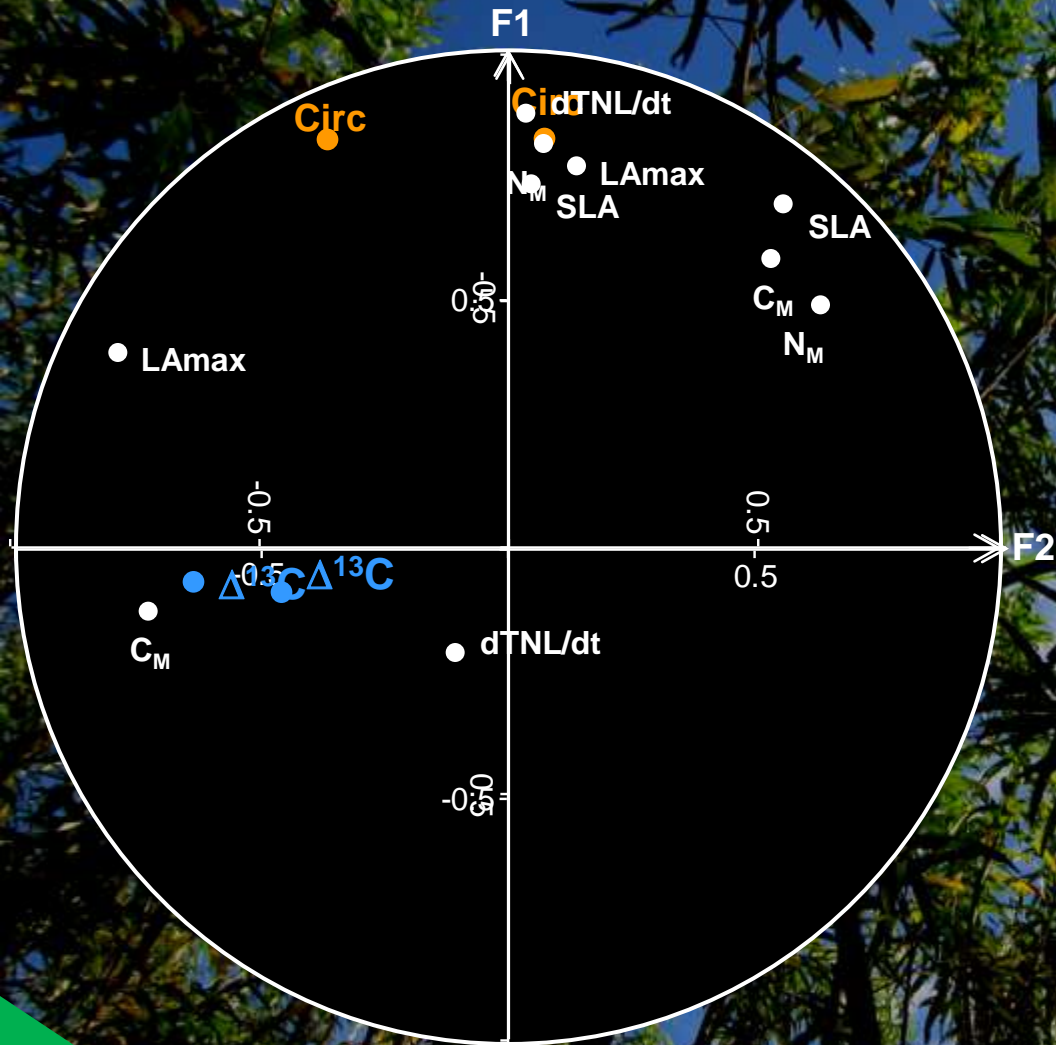
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European poplar clones (Belgian F1)



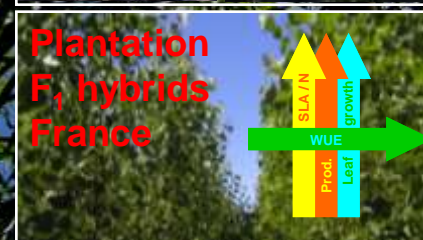
Marron *et al.* 2005



Monclus *et al.* 2005

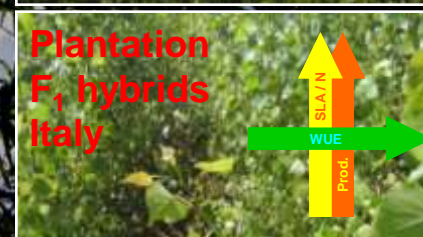


Monclus *et al.* 2006



Marron and Ceulemans 2006

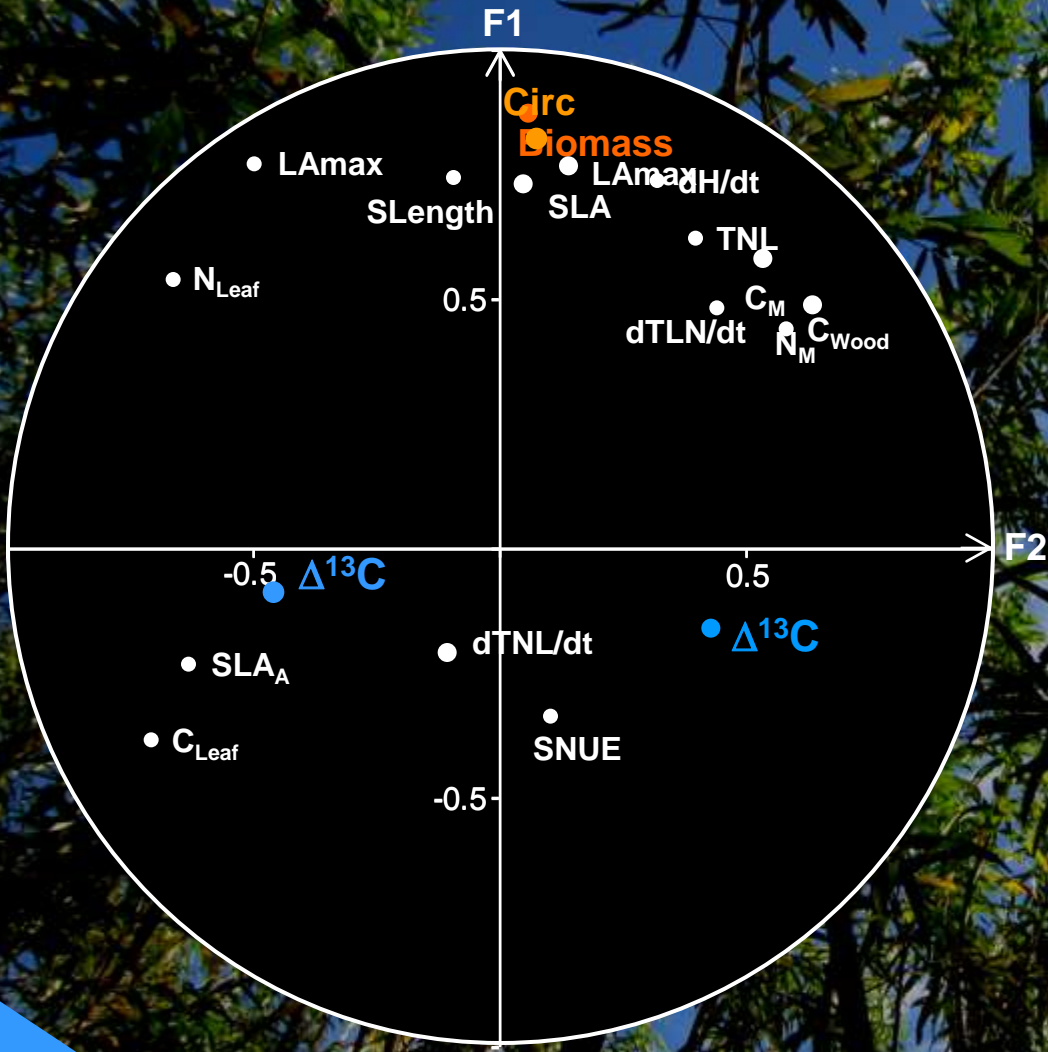
Dillen *et al.* 2011



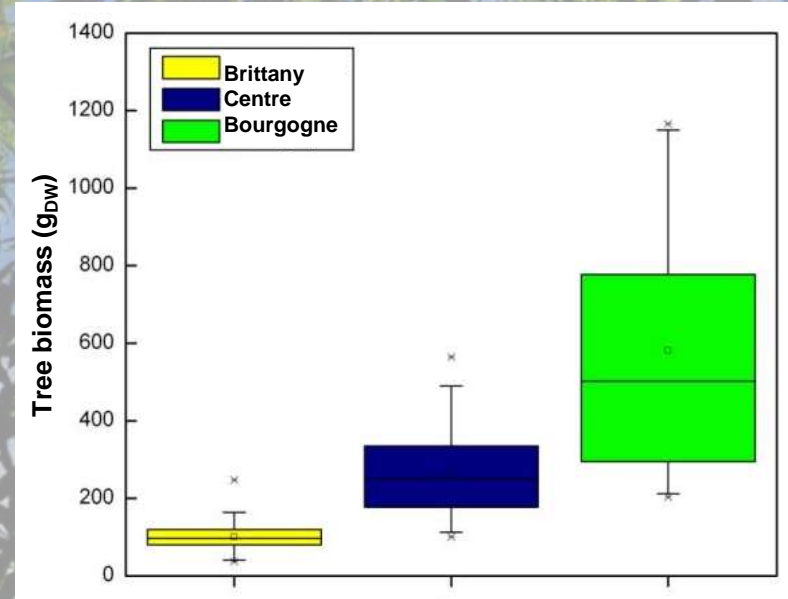
Marron *et al.* 2007

Dilleff *et al.* 2011

European willow clones (Sweden / Ireland)



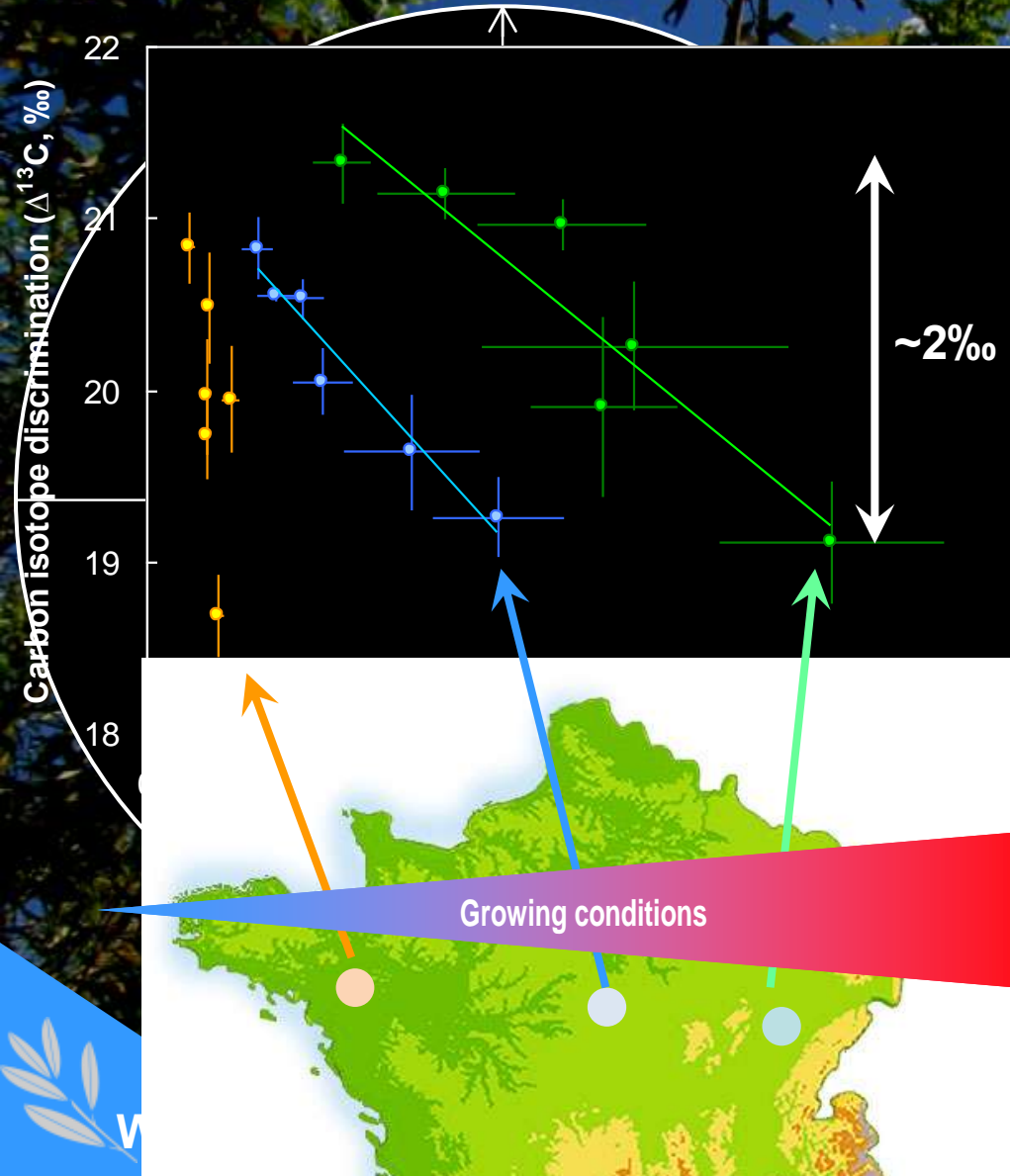
Six willow clones at 3 contrasting sites



For willow as well, it seems that there is no relationship between productivity and Δ / WUE

But...

European willow clones (Sweden / Ireland)



... when studied site by site...

Around 30% variation in Δ among willow clones

Clone ranking stable among sites

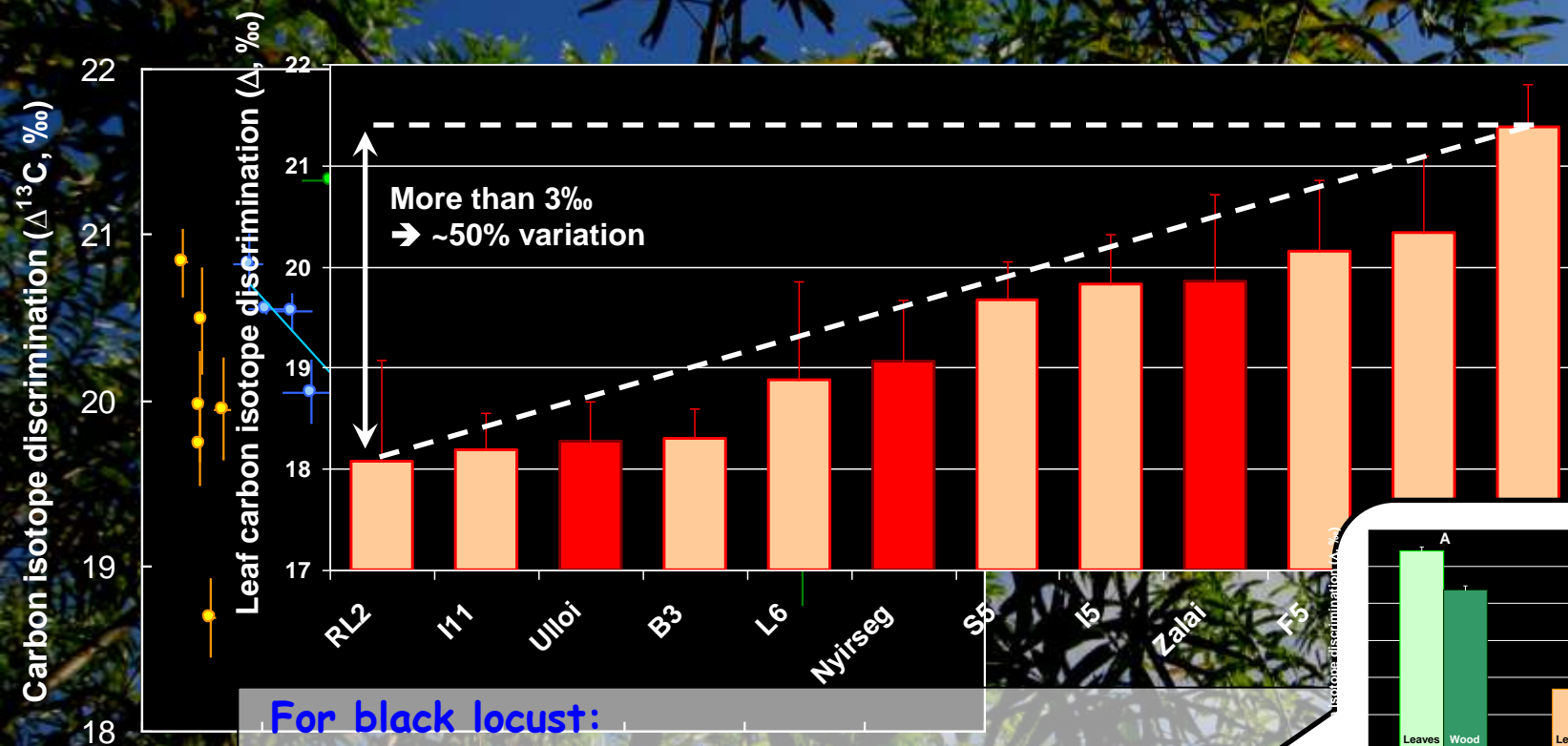
→ Quite wide variation enabling selection

Relation Δ / biomass stronger when conditions are favorable

→ Δ driven by assimilation at the "good" sites

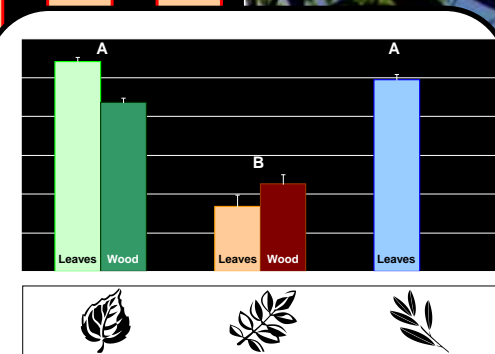
→ Δ driven by stomatal conductance at the "bad" site

European black locust clones (Hungary / France)



For black locust:

- Large clonal variation available in French and Hungary
- But difficulties to propagate it clonally
- Contradiction between seedling Δ (17.2‰) and cutting Δ (19.5‰)
- Need to describe in more details this promising species for bioenergy



Why?

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In summary:

Variation

- Large Δ / WUE variation for the three species...

... but highly dependant on growth conditions

Clonal rankings usually stable whatever conditions

Relation with productivity

Poplar / Robinia: no link between Δ and production has been shown

Willow: negative link Δ / production (positive WUE / prod.)

➔ In any case, possibility to select for both traits together

➔ To be completed...



**Thank you...
... and to the people
contributing to these projects**

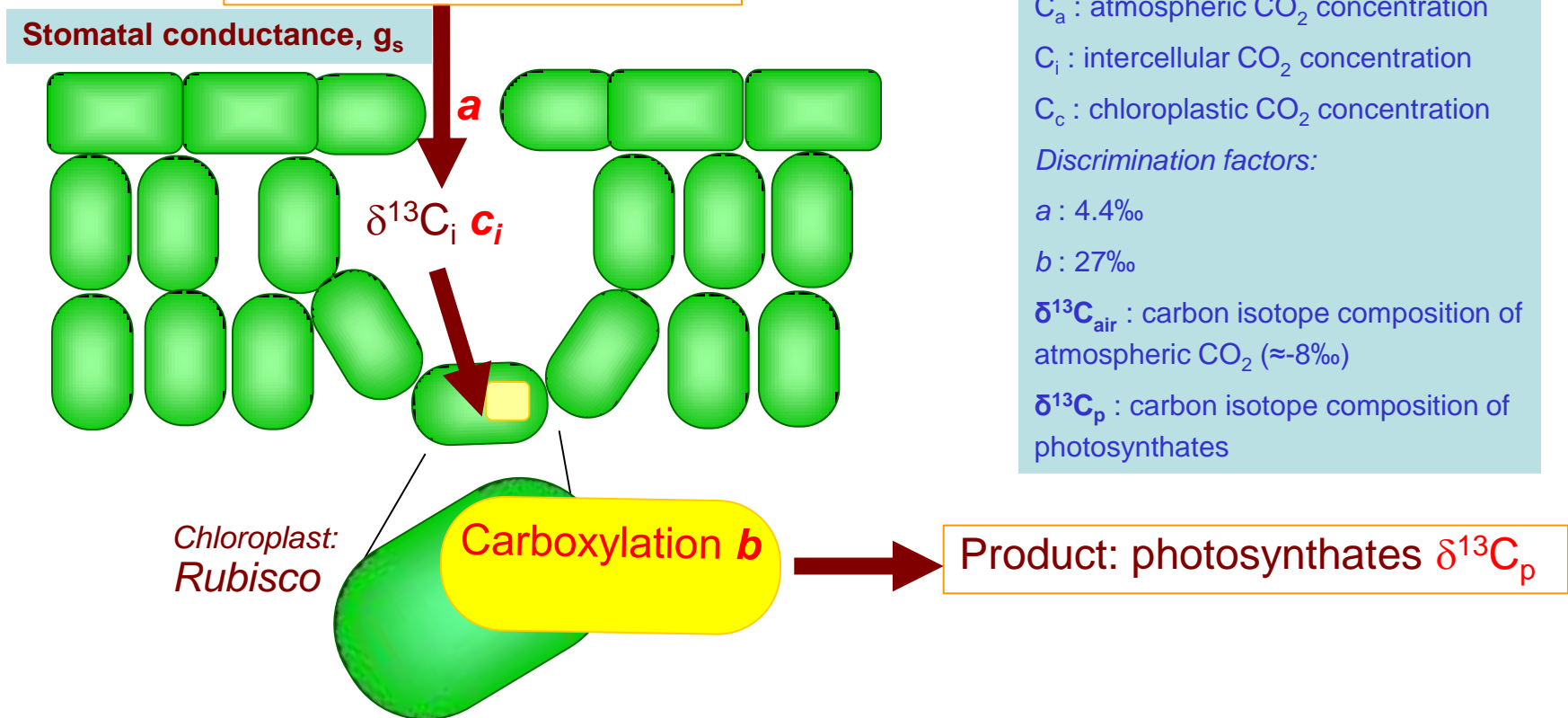
Carbon isotope discrimination during photosynthesis and W_i : simple model

$$\Delta^{13}C \approx \delta^{13}C_{air} - \delta^{13}C_p$$

$$W_i = \frac{c_a}{1.6} \left(\frac{b - \Delta^{13}C}{b - a} \right)$$

Farquhar *et al.* 1984

Source: atmospheric CO₂
 $\delta^{13}C_{air}$ c_a



c_a : atmospheric CO₂ concentration
 c_i : intercellular CO₂ concentration
 c_c : chloroplastic CO₂ concentration