Carbon balance of a cutover bog in the Jura mountains at different stages of regeneration

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Peatlands : carbon sinks

A considerable stake in the actual context : as illustrated by these extracts of the Kyoto Protocol (1992) :

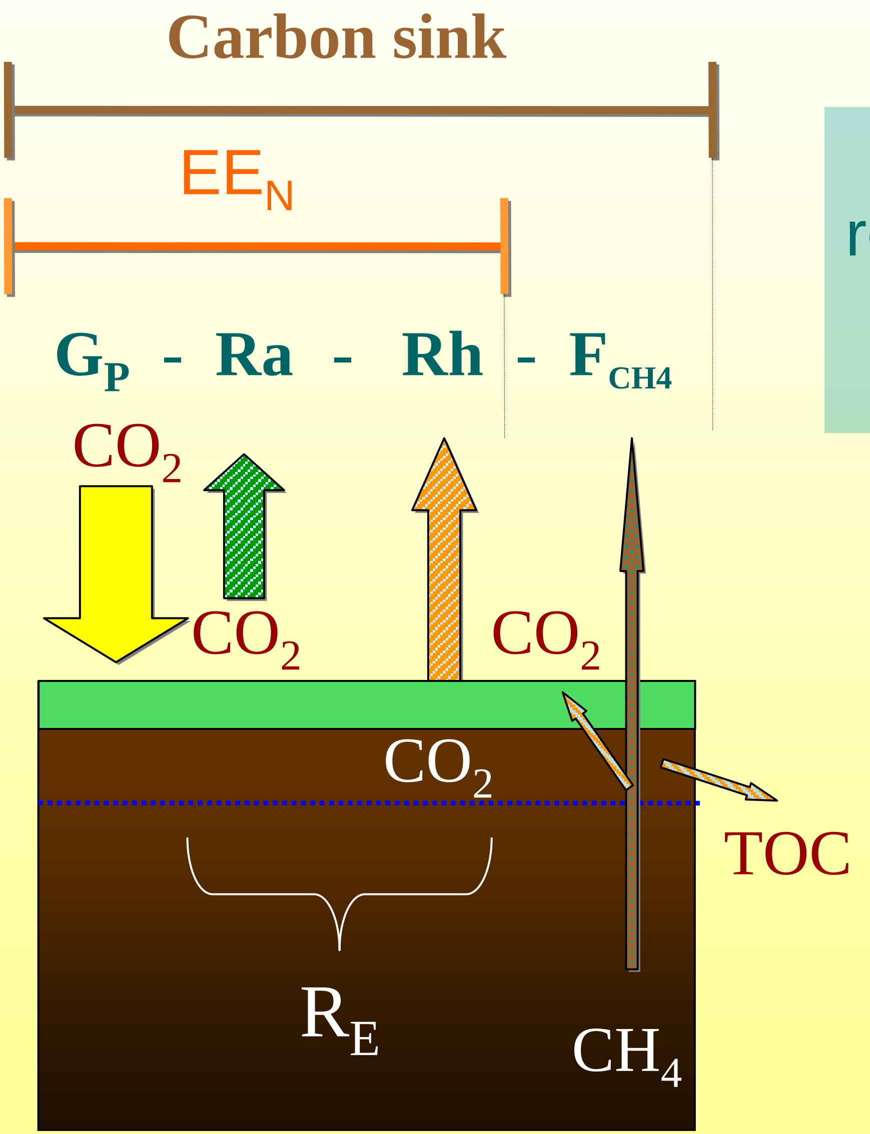
Article 7

"1. Each Party (...) shall incorporate in its annual inventory of anthropogenic emissions by sources and removals by sinks of greenhouse gases (...)"

Article 10b

(ii) "Parties (...) contribute to addressing climate change and its adverse impacts, including the abatement of increases in greenhouse gas emissions, and enhancement of and removals by sinks (...)"

After exploitation, carbon sink ?



At which time in the regeneration process does the peatland again become a carbon sink?

This is one of the problematic issues of the European project RECIPE.

Objectives :

- The role of the key vegetation communities in the re-establishment of a carbon sink.

- The compartmentation of carbon fluxes.

- The building of an empirical model in order to establish a carbon balance for different stages of regeneration.

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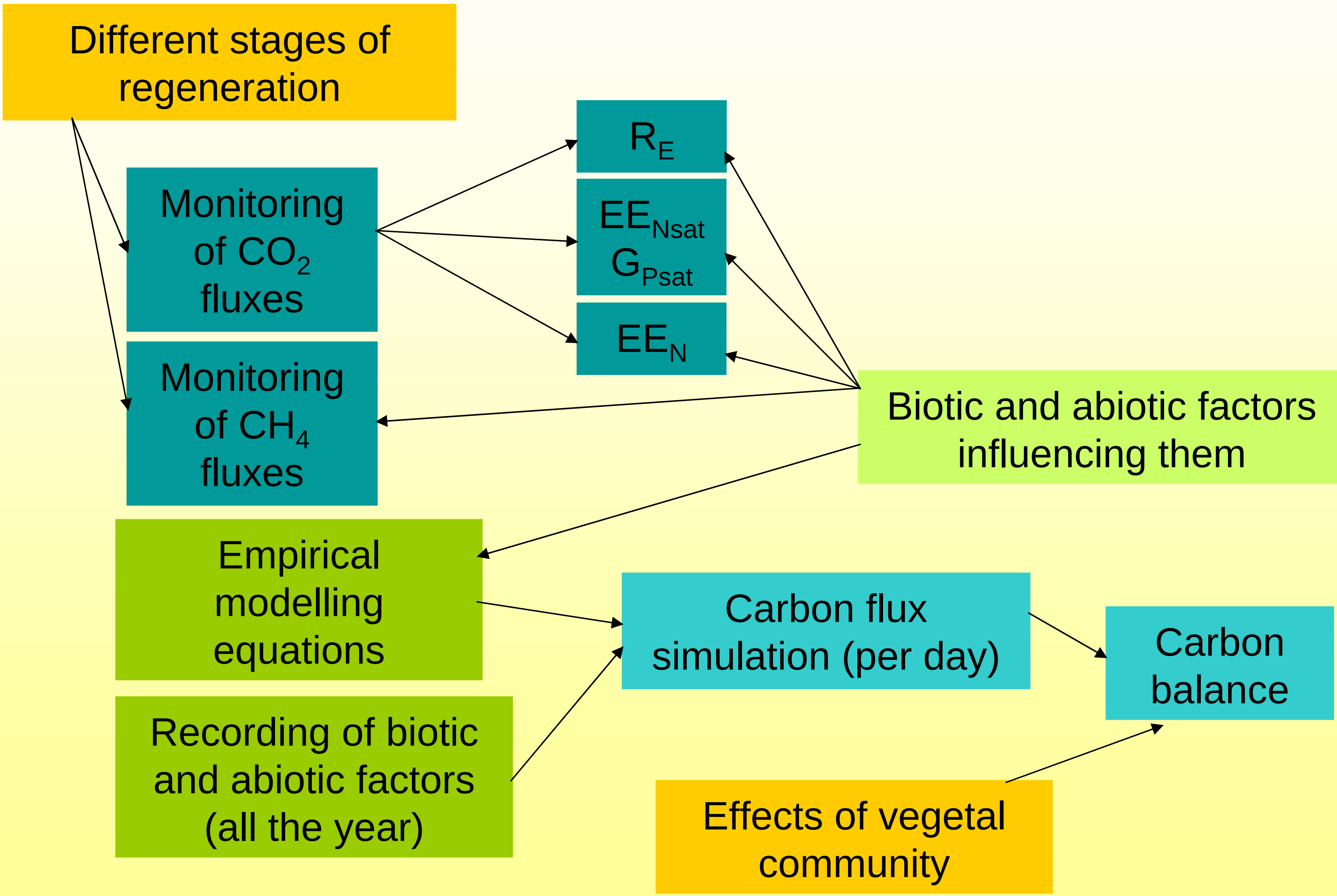
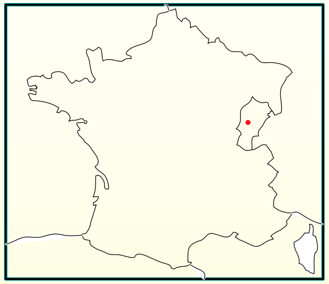
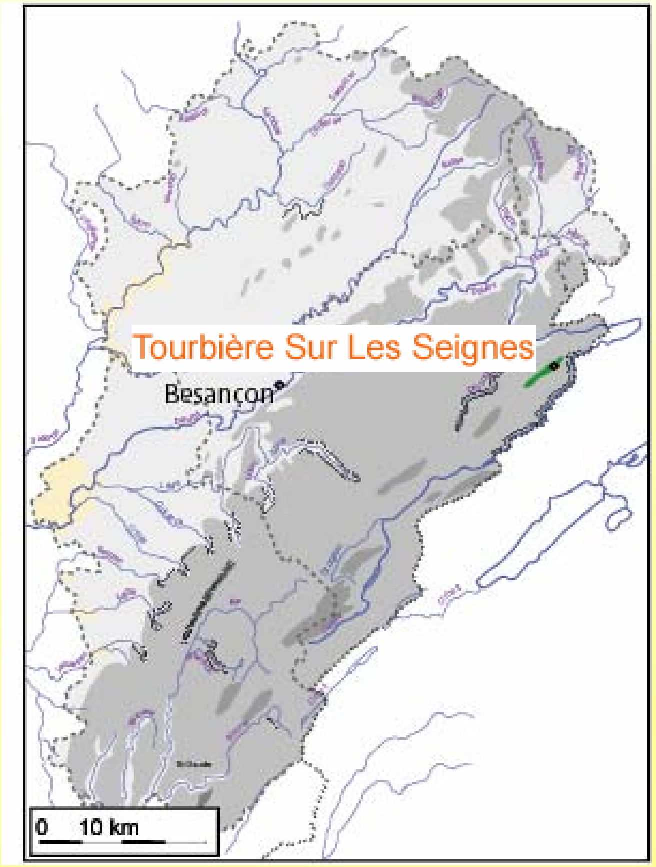

Different stages of regeneration
Monitoring of CO_2 fluxes
Monitoring of CH_4 fluxes
R_E
EE_{Nsat}
G_{Psat}
EE_N
Biotic and abiotic factors influencing them
Empirical modelling equations
Recording of biotic and abiotic factors (all the year)
Carbon flux simulation (per day)
Carbon balance
Effects of vegetal community


Materials
and
methods

Studied site



- A bog in the Jura mountains (860m), exploited for horticulture since 1984, visited yesterday.
- Different stages of regeneration.



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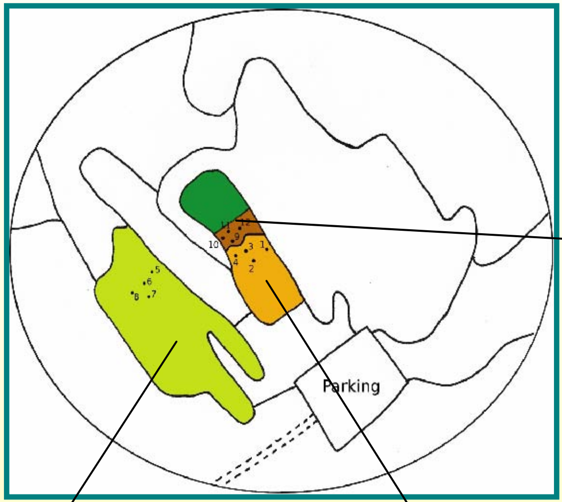
The monitored stations



Bare peat

Advanced regeneration

Recent regeneration

Measurements of CO_2 fluxes

Survey during 2 years (except with snow cover) :

- 11 collars dispatched on the 3 regeneration stages.
- Measurements made with an IRGA (CIRAS 1, ppsystems, U.K.) and an open chamber.

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For EE_{Nsat} and R_E

- Campaign 2004 : once per week (26 days of data acquisition).
- Campaign 2005 : once per three weeks (8 days of data acquisition).

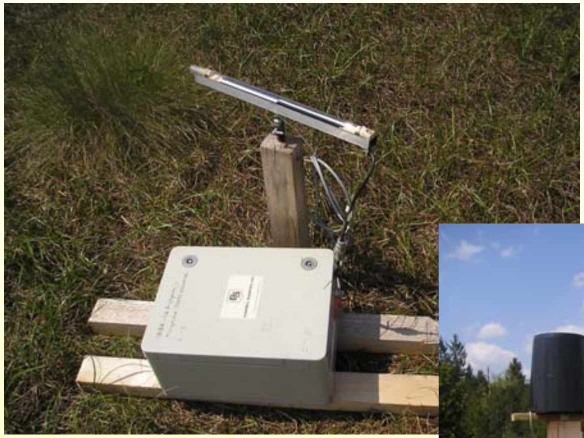
For EE_N without light saturation

- Measurements with artificial shading.

Abiotic and biotic factors

Following during the fluxes measurements :

- Air temperature and PPFD.
- Temperature at 5, 10 and 50 cm.
- Water table level.



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Data acquisition during all the year (time step = ½ h) :

- Global radiation.
- Air temperature.
- Peat temperature at 5 and 30 cm.

Vegetation index (VI) (between 0 to 1) built with :

- Foliar Index (IF) for vascular plants.
- Bryophyte index (BI).
- Visual index of bryophyte dessication (DI).

Methane fluxes

- CH_4 fluxes followed during the two years at each season.
- Incubation in closed and dark chambers.
- Three samples over 75 min in vacuum tubes
(analysed with a micro-GC).

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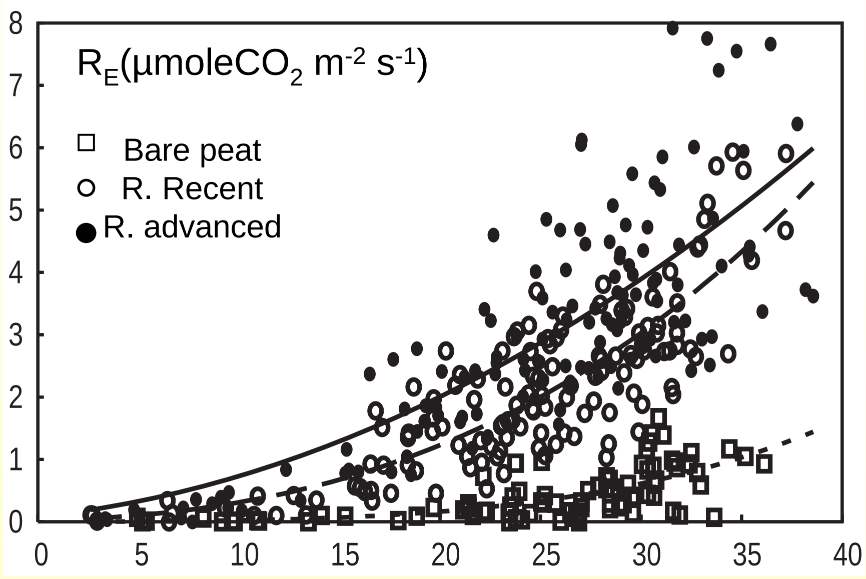
Results
And
discussion

Key factors of R_E

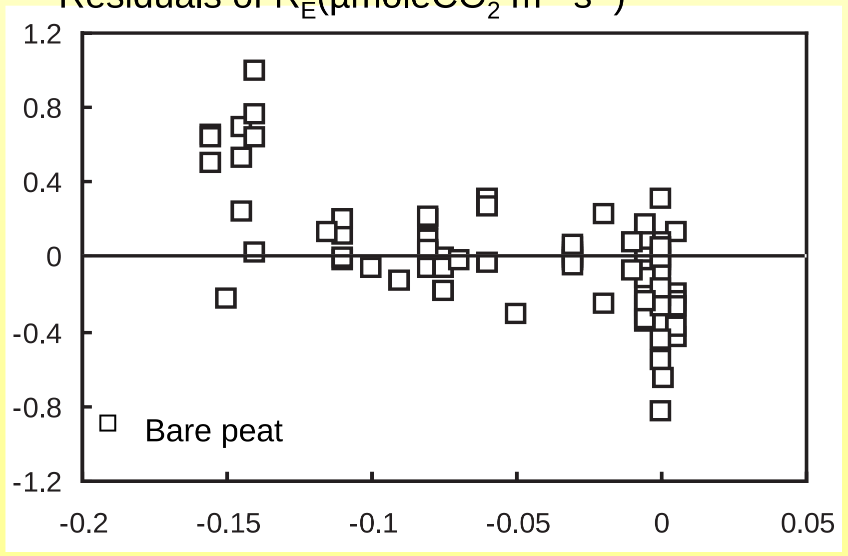
- R_E function of temperature.
- Best answer with :
  - ***Air temperature***
  - ***Power function***

$$R_E = \alpha * \left(\frac{(T_A - T_{min})}{(T_{rèf} - T_{min})} \right)^b$$



- On bare peat :
  - Residuals linked with the water table level.

$$R_E = \left(a * \frac{WT}{WT_{rèf}} + c \right) * \left(\frac{(T_A - T_{min})}{(T_{rèf} - T_{min})} \right)^b$$



CO_2 fluxes discussion

• Respiration

- Air temperature :

- First factor which explains R_E variations (Lafleur *et al.* 2005).

- Water table level :

- Bare peat with high water table level : low CO_2 fluxes.

- Vegetation index :

- High contribution to respiration.

• Growth photosynthesis and Net Ecosystem Exchange

- Bryophyte desiccation : key factor for P_{Gsat}
- Vegetation index : takes into account both types of vegetation

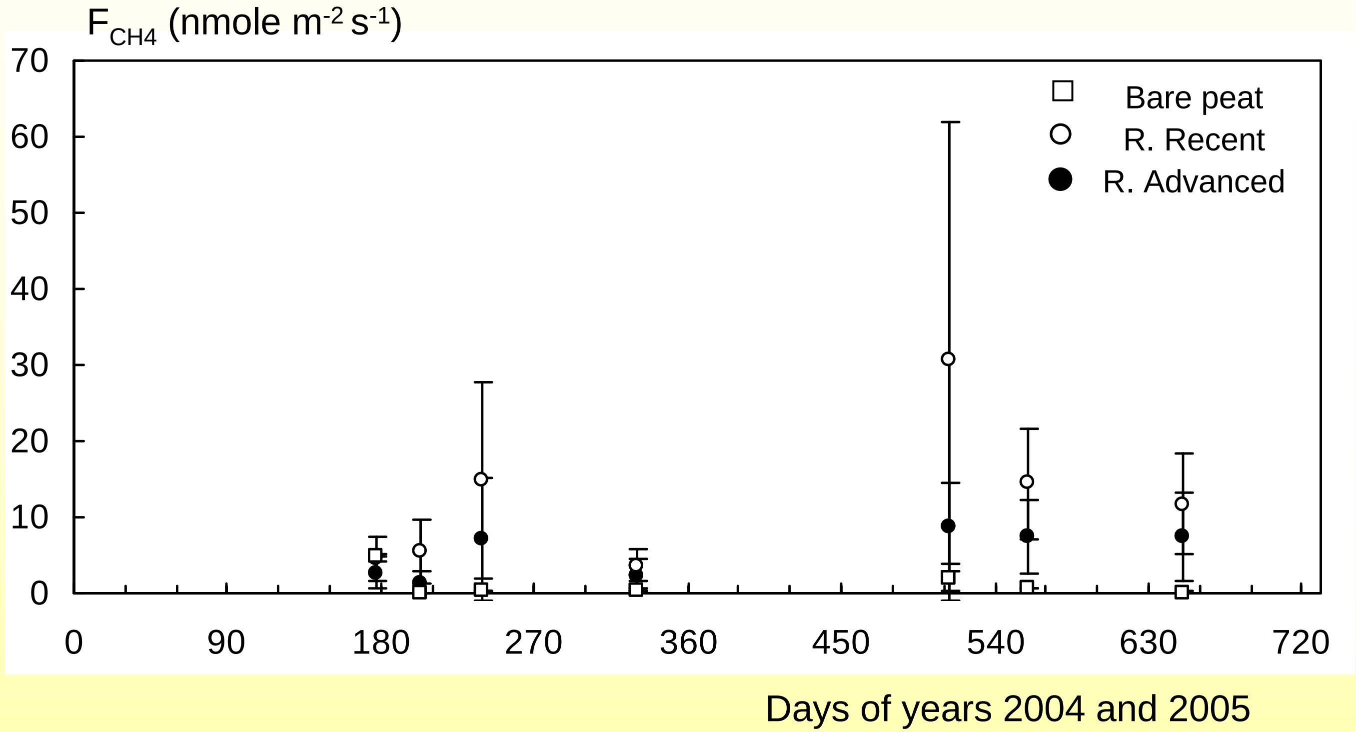
  $\Rightarrow$ *Good simulation*

  - at the site

  - at the intra-site micro-heterogeneity

  - at the variations between the two years of measurements.

Methane fluxes



-Low fluxes.

-The highest fluxes in the recent regeneration.

-The lowest fluxes on bare peat.

- High intra-site variability.

Methane fluxes : discussion

- CH_4 fluxes linked to foliar index, two possible types of interactions :
  - *Methane ducting*
  - *Organic carbon availability (Mikkelä et al. 1995).*

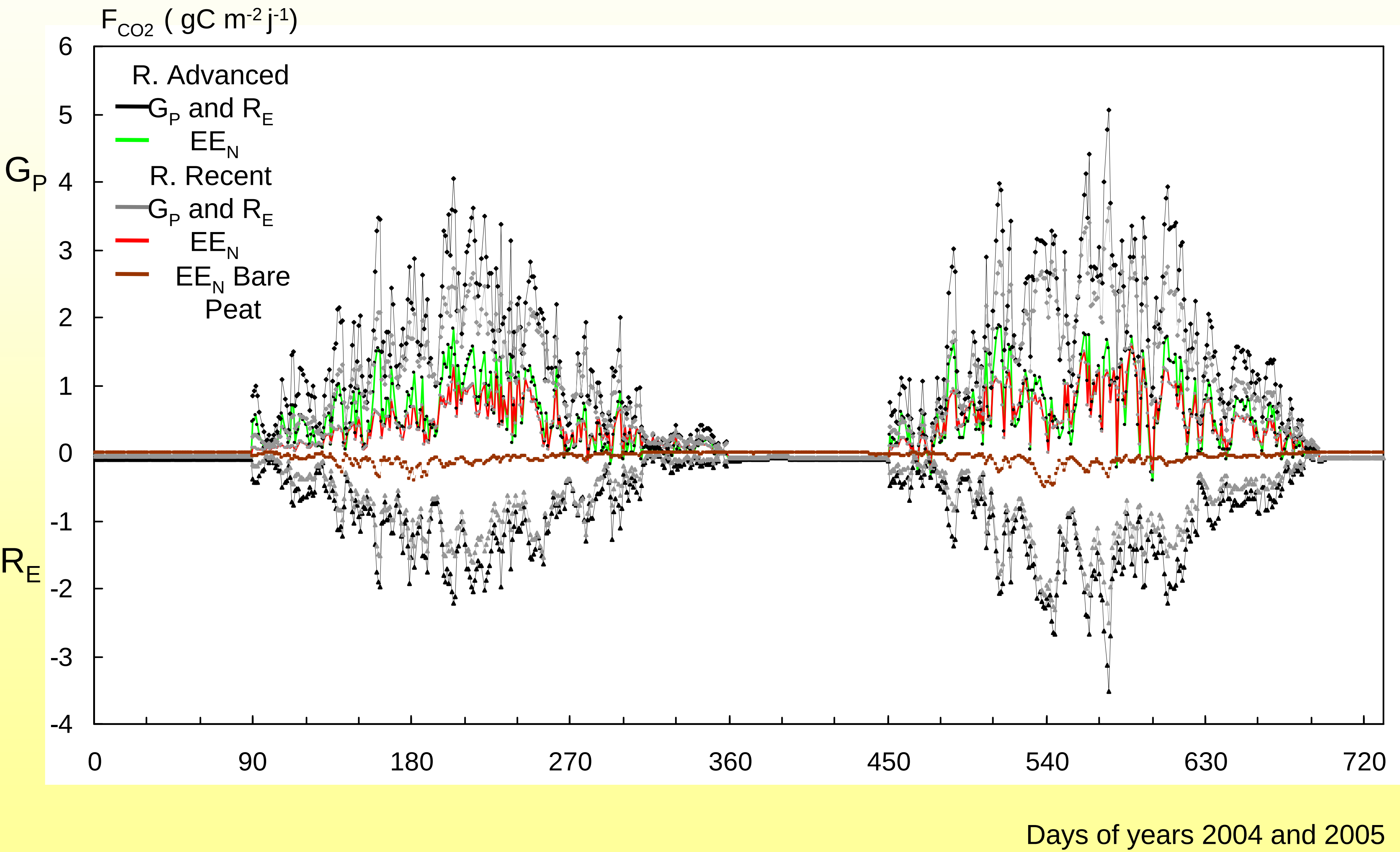
- Highly decomposed peat, low CH_4 (Glatzel *et al.* 2004).

- CH_4 fluxes and water table level :
  - *Concomitant augmentation of temperature.*

- Comparison with the data of dissolved CH_4 and CO_2 along the peat profile (followed during the two years) :

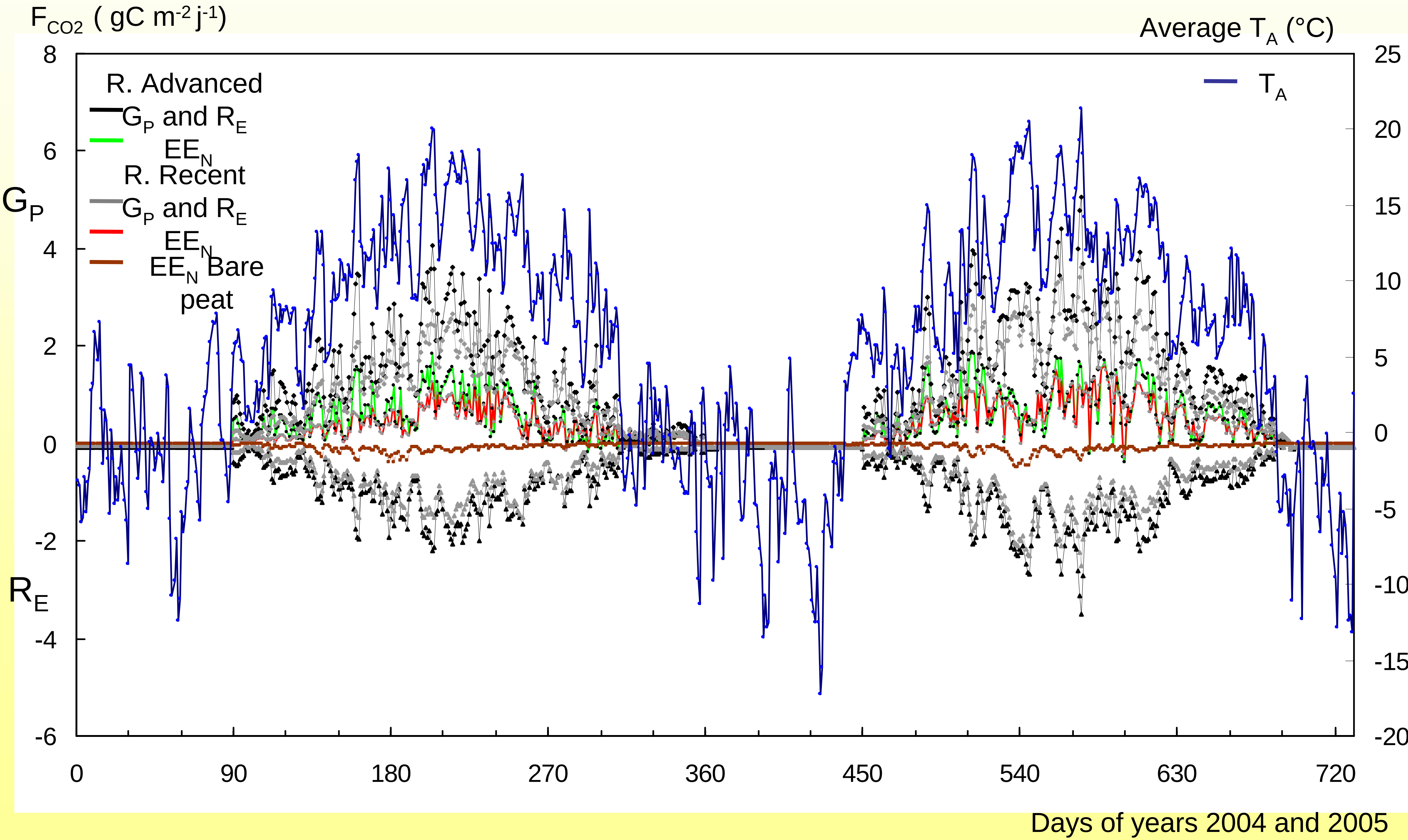
  $\Rightarrow$ Additional information on the surface fluxes.

Daily fluxes simulated



Daily fluxes simulated

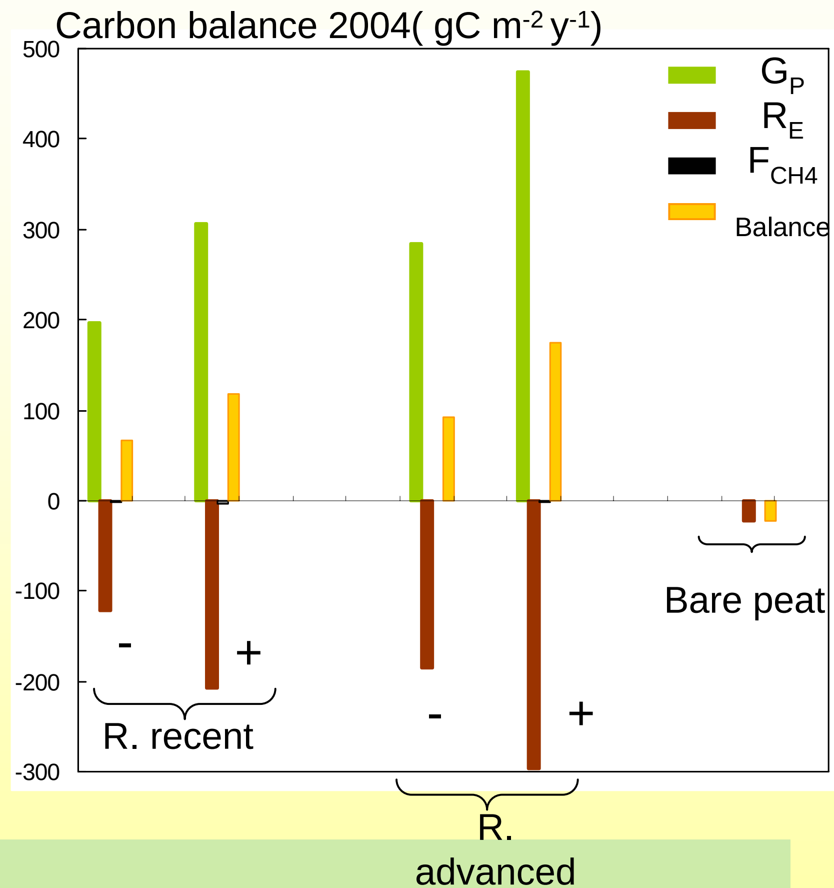
Effects of air temperature daily variations



Carbon balance

Annual estimated carbon balance compartments
($g\ C\ m^{-2}\ y^{-1}$)

2004	Bare peat	R. recent	R. advanced
G_P		197 ~ 306	284 ~ 474
R_E	-22	-121~ -207	-186 ~ -297
F_{CH4}	-0.4	-1.5 ~ -2.8	-0.7 ~ -2.3
balance	-22	67 ~ 118	93 ~ 175
2005	Bare peat	R. recent	R. advanced
G_P		279 ~ 379	359 ~ 525
R_E	-19 ~ -31	-199 ~ -214	-233 ~ -340
F_{CH4}	-0.2 ~ -0.6	-1.8 ~ -3.9	-0.5 ~ -2.7
balance	-19 ~ -32	78 ~ 166	122 ~ 183



The two stages in regeneration :

Carbon sink for both years, higher in the R. advanced.

Bare peat :

Weak carbon source.


Conclusion
and
perspectives

Vegetation and carbon fluxes

Two distinct stages of regeneration :

R. advanced, dominated by Sphagnum :

- *Carbon sink slightly more elevated.*
- *Drought impact.*

R. recent, dominated by vascular plants :

- *Weaker drought impact.*
- *More methane released.*

Closed balance between those stages but different processes :

⇒Several possible evolutions in the case of climate change.

⇒ A composite vegetation better adapted to the climate change in term of carbon balance.

Bog Restoration and carbon balance

Bare peat

High WT level

Low CO_2 fluxes

If decomposed peat : low CH_4 fluxes

Return facilitated to a typical bog vegetation

Low WT level

High CO_2 fluxes

low CH_4 fluxes

Hard to return to a typical bog vegetation

Vascular plants :
- Bryophytes protected against drought
- Increase of CH_4 fluxes

Bryophytes :
- Good accumulation
- Sensitivity to drought

Favour a mixed vegetation

Perspectives

A better comprehension of physiological processes of the different key vegetal species and of microorganisms

↓

Starting up of more mechanistic models

↓

Scenario testing of climate changes or of restoration

Molecular and microscopic approaches of material degradation processes (RECIPE).

Isotopic measurements per key vegetal species and for different peat types.

Measurements of CO_2 fluxes at leaf or *Sphagnum* plant scale.

Evaluation of C loss through DOC and VOC.

Merci,

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au Laboratoire de Biologie Environnementale,

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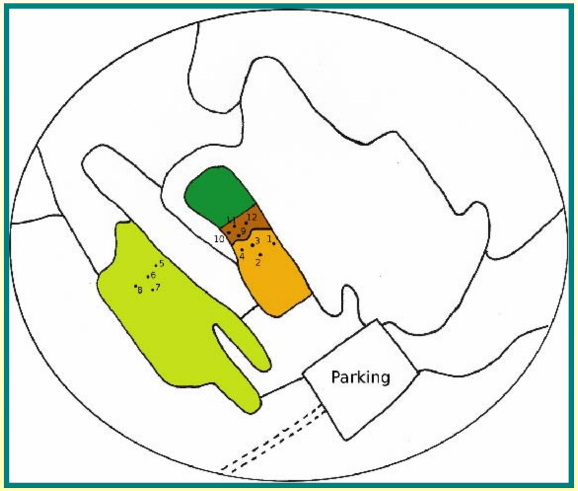
et Alexandre Buttler.

Studied vegetation stages

• **Bare peat (brown) : without vegetation,**

Water table level near the surface all the year.



• **Recent regeneration (orange) :**

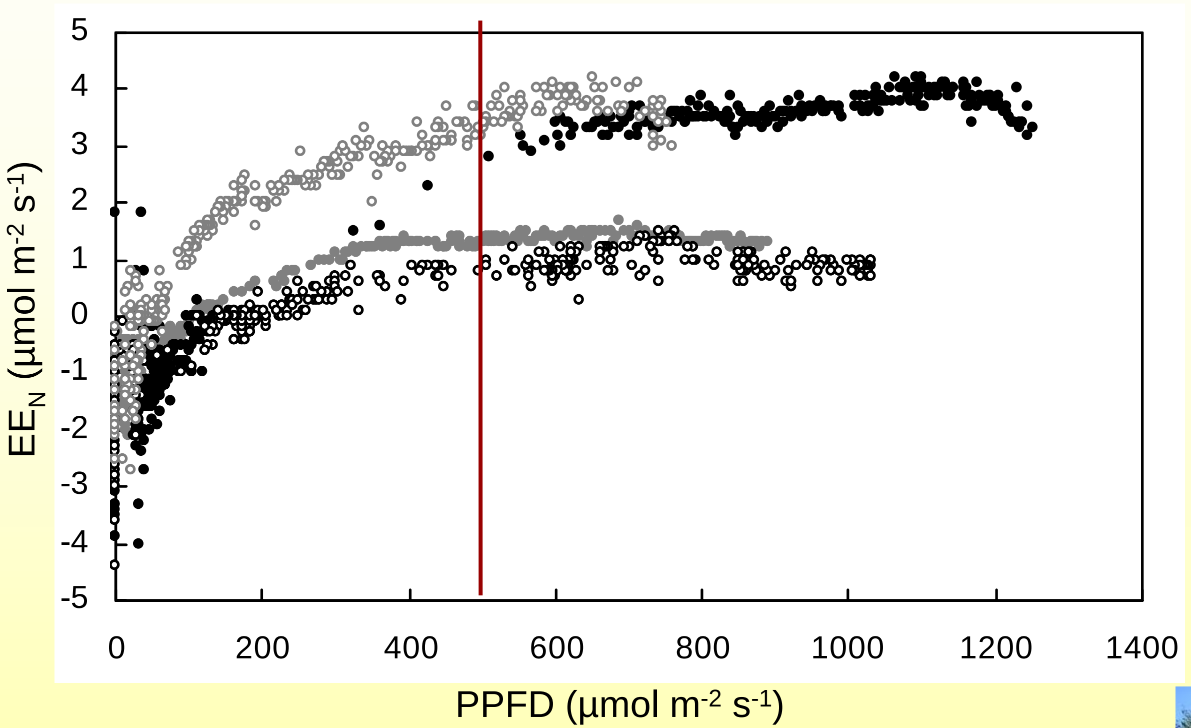
Majority of *Eriophorum angustifolium* and installation under them of *Sphagnum fallax, S. rubellum and S. magellanicum and Polytrichum strictum.*

• **advanced regeneration (pale green) :**

- *Eriophorum vaginatum* and *Sphagnum fallax, S. rubellum and S. magellanicum and Polytrichum strictum.*

- Four times more bryophytes and less vascular plants than on the recent regeneration.

Measurements of CO_2 fluxes without light saturation



Threshold of light saturation at 500 µmol m^{-2} s^{-1}.

The method keeping artificial shading:

- Four levels of shading obtained under the threshold of saturation (between 400 to 70 µmol m^{-2} s^{-1}).

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Abiotic factors

Monitoring during the fluxes measurements :

- Air temperature and PPFD.
- Temperature at 5, 10 and 50 cm.
- Water table level.

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Data acquisition during all the year (time step = ½ h) :

- Global radiation.
- Air temperature.
-Peat temperature at 5 and 30 cm.

Biotic factors

- Foliar Index (IF) for vascular plants :
  - ***Length of marked leaves $\Rightarrow$ surface average.***
  - ***Number of leaves per collar.***

- Bryophytes index (BI) :
  - Surface covered and density.

- Visual index of bryophytes dessication (DI):
  - From 1 (completely dessicated) to 6 (flooded).

- Vegetation index (VI) (between 0 to 1) :

$$VI = \frac{\left(IF + BI * \left(\frac{DI}{DImax} \right) \right)}{(IFmax + BImax)}$$

Empirical model

Empirical model : bare peat site

$$EE_N = \left(a * \frac{WT}{WT_{rèf}} + c \right) * \left(\frac{(T_A - T_{min})}{(T_{rèf} - T_{min})} \right)^b$$

$$F_{CH_4} = j * WT$$

Empirical model ; sites with vegetation

$$EE_N = \left(\frac{i * PPFD * f * VI * e^{-\left(\frac{T_A - g}{h}\right)^2}}{f * VI * e^{-\left(\frac{T_A - g}{h}\right)^2} + i * PPFD} \right) - \left[\left(d * \frac{WT}{WT_{rèf}} \right) + (e * VI) \right] * \left(\frac{(T_A - T_{min})}{(T_{rèf} - T_{min})} \right)^b$$

$$F_{CH_4} = k * IF$$