Integrating 13-y time series of daily SPOT-VEGETATION observation and land-surface modelling to forecast the terrestrial carbon dynamics of Congo Basin forests in a changing climate

The VEGECLIM Project – Bel spo STEREO II Program

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Tropical evergreen forest: large sink and source

Even a small phenology can have significant impact on the global carbon cycle, and thus on global dynamics of climate.
What do we know about Amazonian forest leaf phenology?
Leaf phenology detection in Amazon forest?

Field studies

« Unexpected Seasonal Fluxes in Amazon Forests »
(Saleska et al. 2003)

Satellite observations

“Amazon rainforests green-up with sunlight in dry season”
(Huete et al. 2006)

- Leaf litterfall data
  (Hutyra et al., 2007, Malhado et al., 2009)

Adapative mechanisms to the main limiting factor?

- Leaf flushing in the dry season to optimize access to light

\[ \text{SZA} \downarrow \]

\[ \text{EVI} \uparrow \]
13-y SPOT-VGT daily obs. reprocessing in 10-d. composite of vegetation indices (EVI, NDVI, NDWI)

10-d 1-km SPOT-VEGETATION

\[ EVI = 2.5 \frac{\rho_{NIR} - \rho_R}{\rho_{NIR} + C_1 \rho_R - C_2 \rho_B + L} \]

K67 Santarem site

EVI increase during the dry season obviously not a simple consequence of illumination geometry
Relations between EVI and GPP from fluxtower

SPOT-VEGETATION EVI along the GPP fluxtower measurements at Santarém K67

→ EVI provides useful information about vegetation change
→ Leaf phenology could be driven by solar radiation availability
→ Leaf seasonal dynamics needs to be implemented in models
A SEASONAL LEAF LITTER AND LEAF ONSET SCHEME WAS INTRODUCED IN ORCHIDEE

\[ Litter_{\text{leaf}} = NPP_{\text{leaf}} \]

the new turnover scheme also changes the leaf age class distribution
Resulting modified leaf turnover at Guyaflux (French Guiana)

\[ \text{Litter}_{\text{leaf}} = \text{NPP}_{\text{leaf}} \]
Both order of magnitude and seasonal variations in GPP improved due to introducing seasonal changes in $V_{c,\text{max}}$. Resulting seasonal changes in GPP at Guyaflux (French Guiana).
Correlation of EVI - GPP simulated by ORCHIDEE

EVI from SPOT-VEGETATION

GPP simulated by ORCHIDEE (PFT2, NLT version)
High and positive temporal correlation all over the basin between EVI and GPP simulated from the ORCHIDEE model.
What about the Congo basin leaf phenology?
Resulting modified leaf turn over at Dimonika (DR Congo)

Mayombe (04°11’S 12°23’E)
dense evergreen to semi-deciduous Equatorial coastal forest

![Graph showing leaf litterfall over time with different lines representing various methods and years.]
**SPOT-VGT time series affected by clouds and AOT**

- EVI strongly contaminated by very low number of valid observations due to the cloud cover in the West of the basin, from May to December.

- Nbr of valid observation

- Aerosol Optical Thickness
Similar BRDF effect than in Amazon forest but seasonal SPOT-VGT profile very different

- BRDF and angle configuration very similar to K67 in the Amazon basin
- EVI patterns strongly differ from K67 in the Amazon basin
EVI and GPP simulated by ORCHIDEE

AGWB Kearsley et al., 2013:
YANG 163 ± 19 tC.ha⁻¹
DJA  217 ± 16 tC.ha⁻¹
ITURI 259 ± 28 tC.ha⁻¹

AGWB Simulation with Orchidee:
YANG 197.3 tC.ha⁻¹
DJA  157.8 tC.ha⁻¹
ITURI 143.3 tC.ha⁻¹
EVI and GPP simulated by ORCHIDEE

EVI from SPOT-VEGETATION

GPP simulated by ORCHIDEE (PFT2, NLT version)

No temporal EVI-GPP correlation (mostly negative)
EVI often contaminated by aerosols and cloud cover.
Ngotto virtual forest to assess respective effects

Raytran model (3D simulation over the Ngotto forest site) provides a better understanding of reflectance drivers (aerosols and other atmospheric components, LAI, leaf reflectance,...) influencing the EVI values thanks to radiative transfer simulation.

3D representation of the tropical canopy, BRF of the scene in the NIR band and canopy vertical structure

(de Wasseige et al., AFM 2008)
Validated DR Congo deforestation model
(UCL, 2014 for FAO-UN REDD)
Impacts of LULCC and climate change on carbon stored in vegetation in 2035

Cumulated net ecosystem exchanges for DRC between 2005 and 2035:

- CC (red): 4.32 PgC
- LULCC + CC (blue): 3.43 PgC
- LULCC (green): 0.96 PgC
- Reference (purple): 1.61 PgC

Emission of **0.91 PgC** due to LULCC
- ~ 1750 km² deforested
- ~ 3% of the carbon stored

Sink of **2.74 PgC** due to climate change
- ~ 7000 km² reforested with mature forest
- ~ 8% of the carbon stored

Cumulated net ecosystem productivity in DRC (gC)
Impacts of LULCC and climate change on carbon stored in vegetation

Impact of LULCC on carbon stocks (GgC)

Impact of climate change on carbon stocks (GgC)
Conclusions and perspectives

- **Relationship between EVI and GPP in the Amazon basin** show that EVI could be useful to describe vegetation dynamics and could be used as proxy to vegetation properties in dynamic vegetation models.

- Vegetation dynamics observations with optical RS is more complex in the Congo basin than in the Amazon basin.

- **DRCongo forests remains a sink up to 2035** combining the climate change and the deforestation model.

- The validation of the GPP estimate for the DRC requires a flux tower and this should finally install one in Yangambi.
Thank you for your attention!
The “green up” theory

Adaptive mechanisms?

- **Leaf flushing in the dry season**: emergence of new leaves to optimize access to light
- **Deep root system** to reach water far below the surface during the dry season

The green-up phenomenon