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Agro-Bio Tech

Digital Energy & Agriculture Lab

Photosynthesis dynamics' effects on yield in standard APV and even lighting configurations

Arnaud Bouvry, Frédéric Lebeau

THE WORLD CONFERENCE
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The issue of light sharing in agrivoltaics

Specific geometry

© TSE

Semi-transparent modules

© KU Leuven

Better light sharing: diffusers

Omnidirectional diffusers

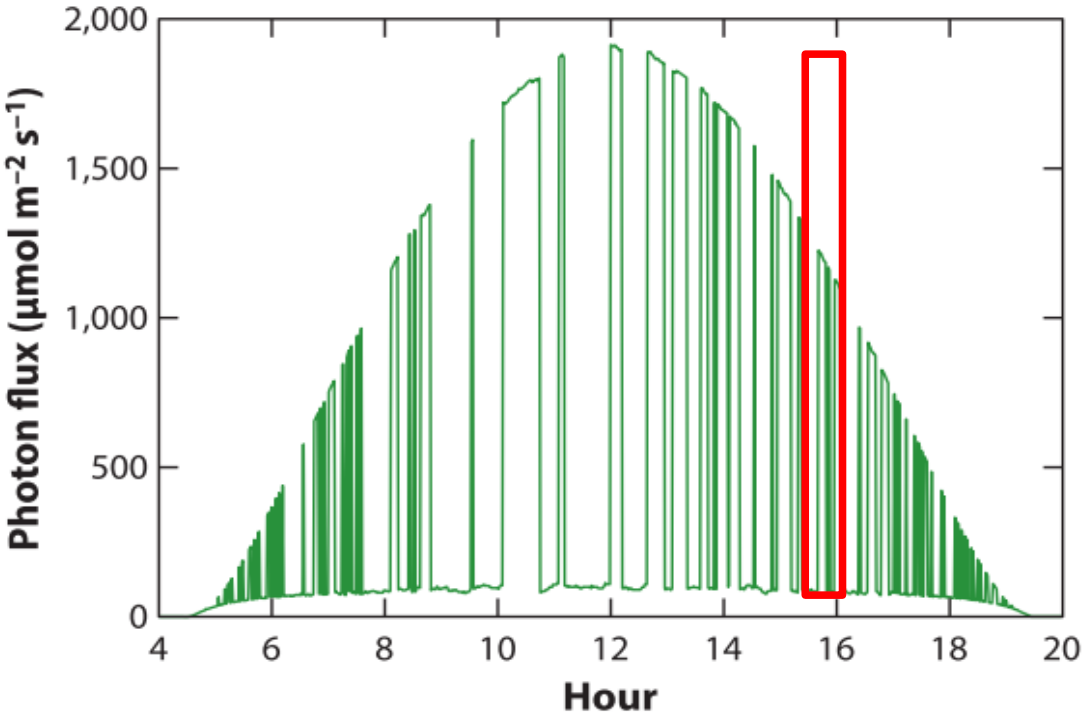
© BayWa r.e.

Directional diffusers

Zheng et al., 2021

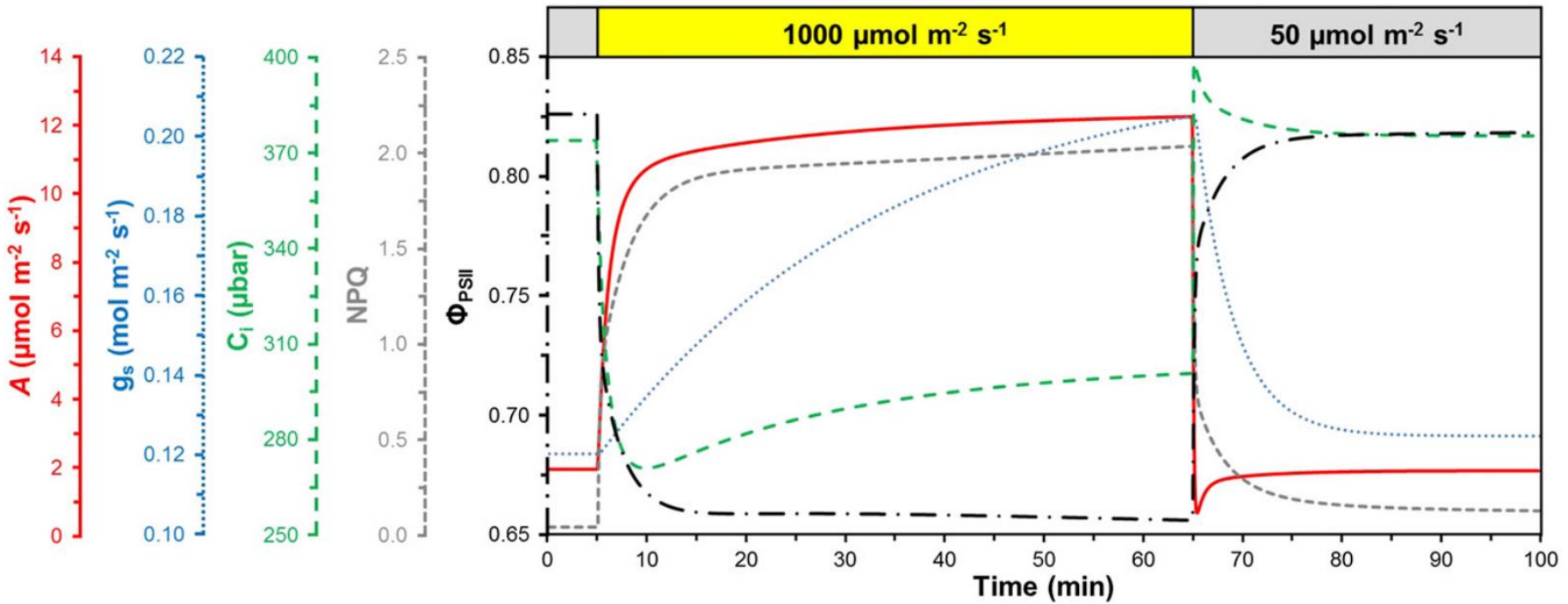
Abrupt changes in irradiance

- Shade/sun and sun/shade transitions
- Sunflecks in the canopy
- Irradiance profile received by a leaf within the canopy



Long et al., 2022

Abrupt changes in irradiance : CO_2 assimilation rate

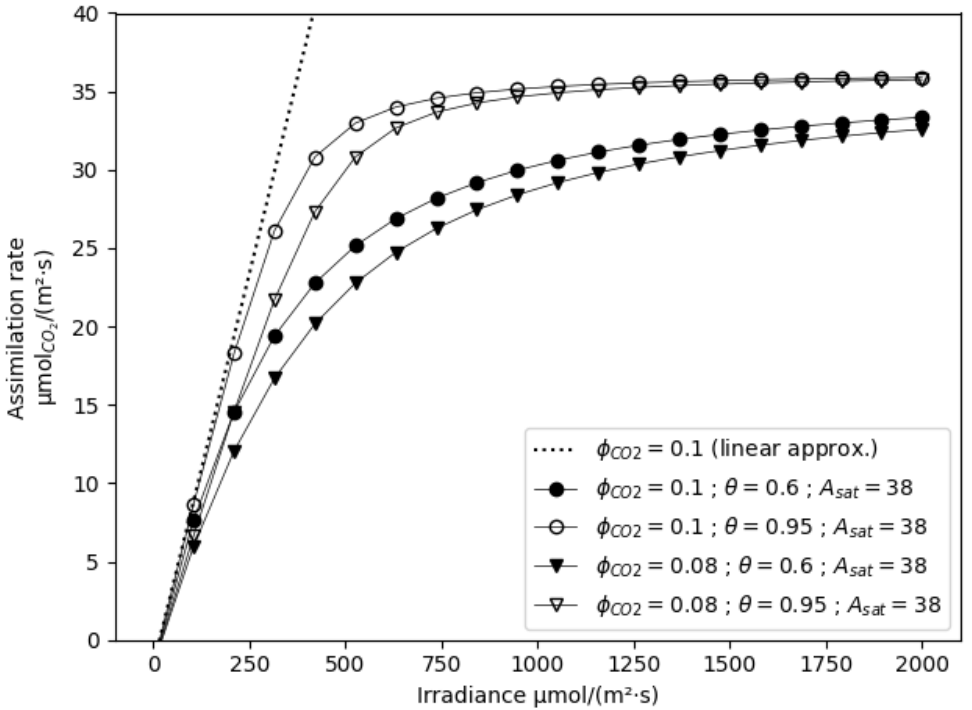


Kaiser et al., 2018

Photosynthesis light-saturation curve

$$\theta A^2 - (\phi_{CO_2} I + A_{sat})A - \phi_{CO_2} I A_{sat} = 0$$

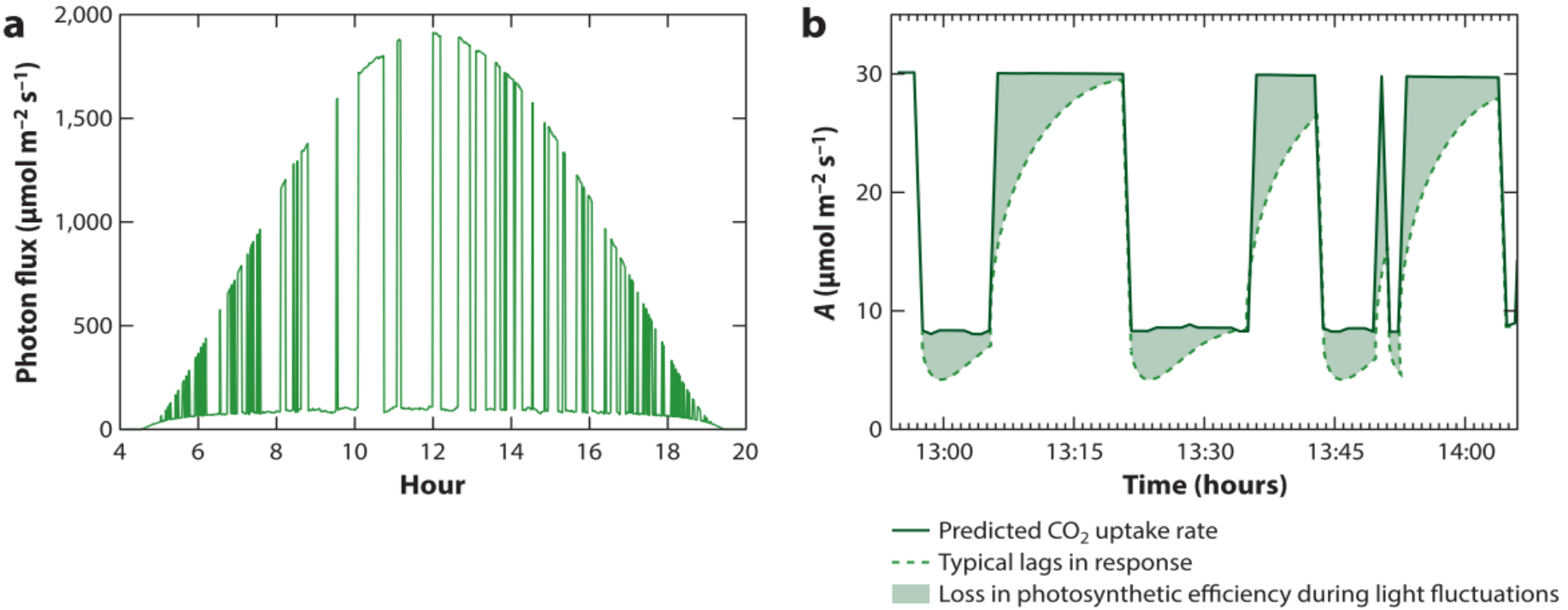
A	CO_2 assimilation rate	$\mu mol \cdot m^{-2} \cdot s^{-1}$
I	irradiance	$\mu mol \cdot m^{-2} \cdot s^{-1}$
A_{sat}	Saturated assimilation rate	$\mu mol \cdot m^{-2} \cdot s^{-1}$
θ	Curvature parameter	[-]
Φ_{CO2}	Origin slope	$\mu mol_{CO2} \cdot \mu mol_{phot}^{-1}$



\+ ← Photosynthesis efficiency → -

Long et al., 1994

Photosynthetic efficiency loss

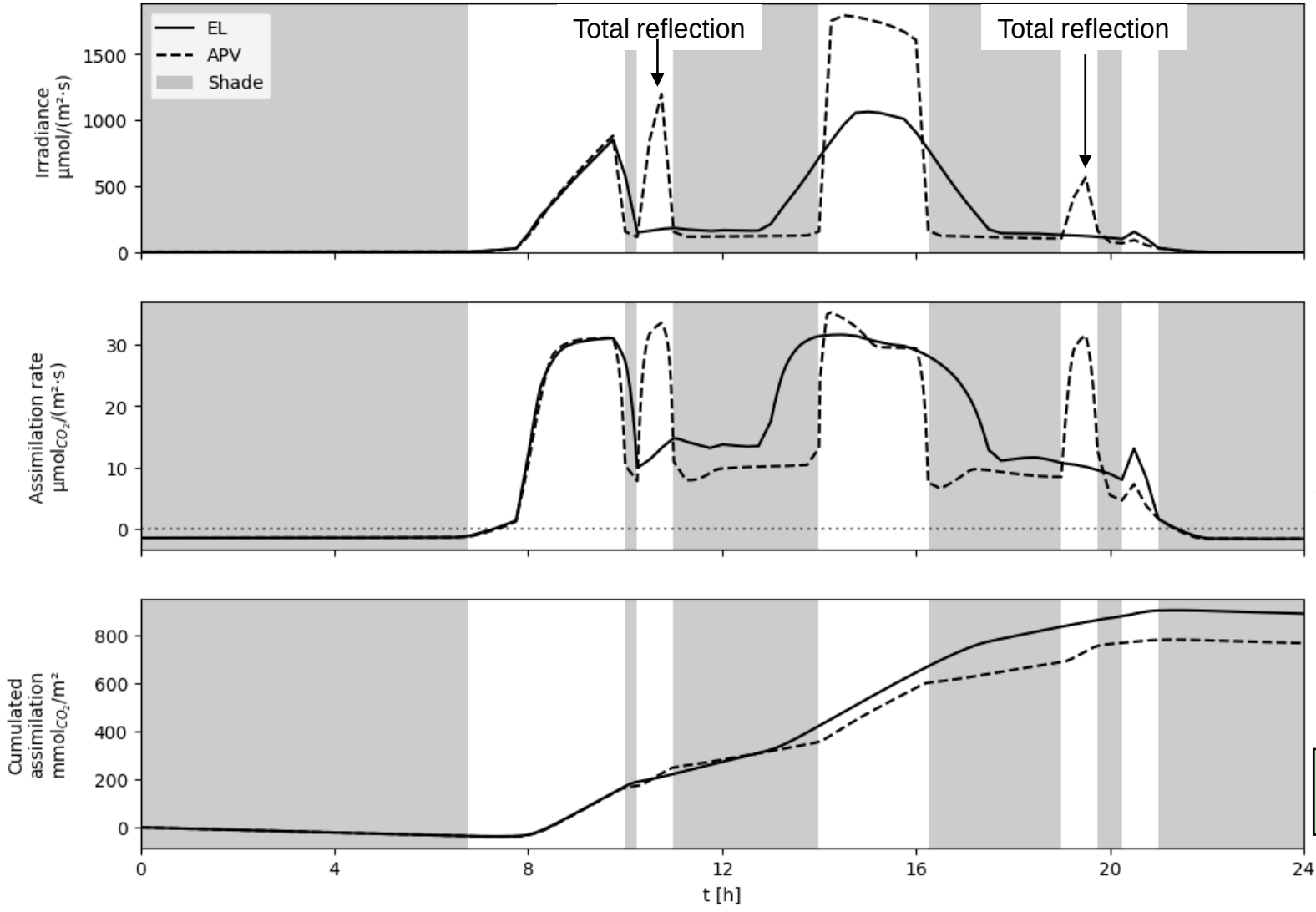


Long et al., 2022

Experimental data

- Open field
- Even lighting
- Standard AV

Photo R. Bruhwyler



Weighted light sum – 1h window

$$I_{int,i} = \sum_{k=i-w}^{i} \frac{I_k}{\frac{1+k}{w \cdot dt}}$$

Cumulated irradiance -16% in EL

Cumulated CO_2 **+14%** in EL

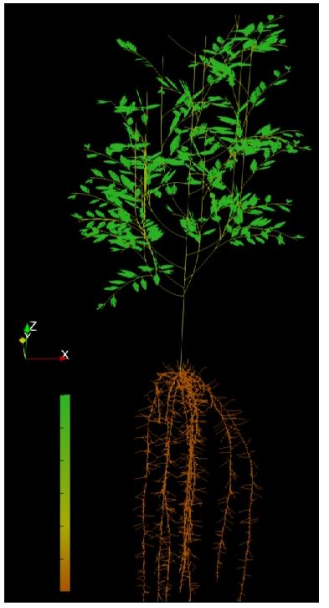
EL increases photosynthesis efficiency

Conclusion

- Directional diffusers :
  - Mitigate abrupt irradiance changes
  - Lower local irradiance
  - Decrease duration in the shade
  - Increase photosynthesis efficiency
- But ! only one component of yield (plant and canopy structure, wind, microclimate, etc.)

  → Comprehensive modeling framework

FSPM: CPlantBox



Zhou et al., 2020

PASE: a Python Agrivoltaic Simulation Environment
Wednesday 10:30 “Optimization and Economic modeling”

Thank you for your attention !

Arnaud BOUVRY

PhD student at Gembloux Agro Bio Tech
Digital Energy and Agriculture Lab

abouvry@uliege.be

LIÈGE université
Gembloux
Agro-Bio Tech
Digital Energy & Agriculture Lab

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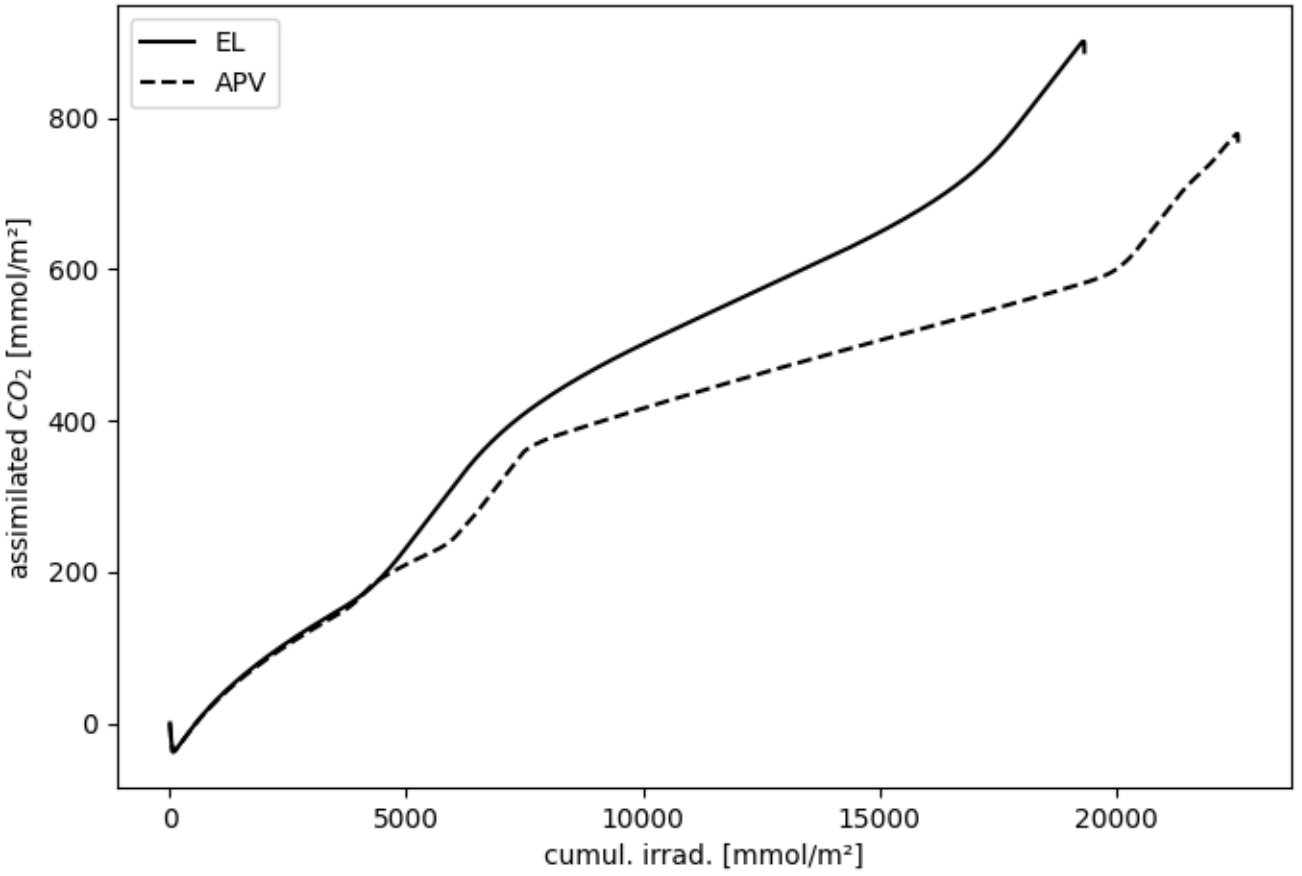

EL
APV
800
600
400
200
0
assimilated CO_2 [mmol/m²]
0
5000
10000
15000
20000
cumul. irrad. [mmol/m²]

Photosynthesis light-saturation curve

$$\theta A^2 - (\phi_{CO_2} I + A_{sat})A - \phi_{CO_2} I A_{sat} = 0$$

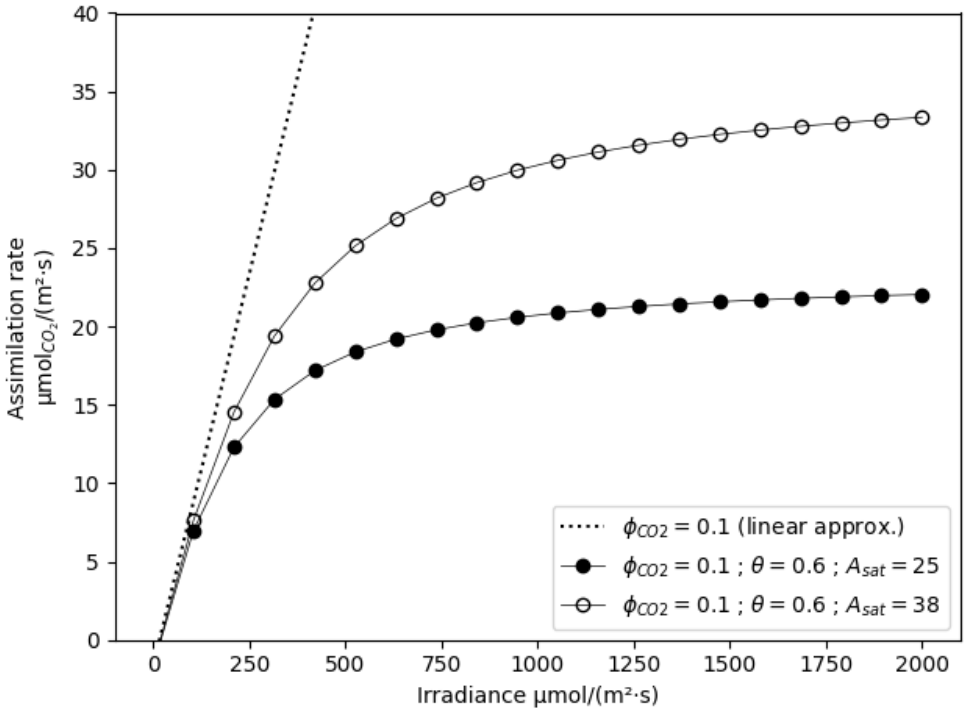
A: CO_2 assimilation rate ($\mu mol \cdot m^{-2} \cdot s^{-1}$)

I: irradiance ($\mu mol \cdot m^{-2} \cdot s^{-1}$)

A_{sat}: saturated assimilation rate ($\mu mol \cdot m^{-2} \cdot s^{-1}$)

θ: curvature parameter (-)

Φ_{CO2}: origin slope ($\mu mol_{CO2} \cdot \mu mol_{phot}^{-1}$)



Long et al., 1994