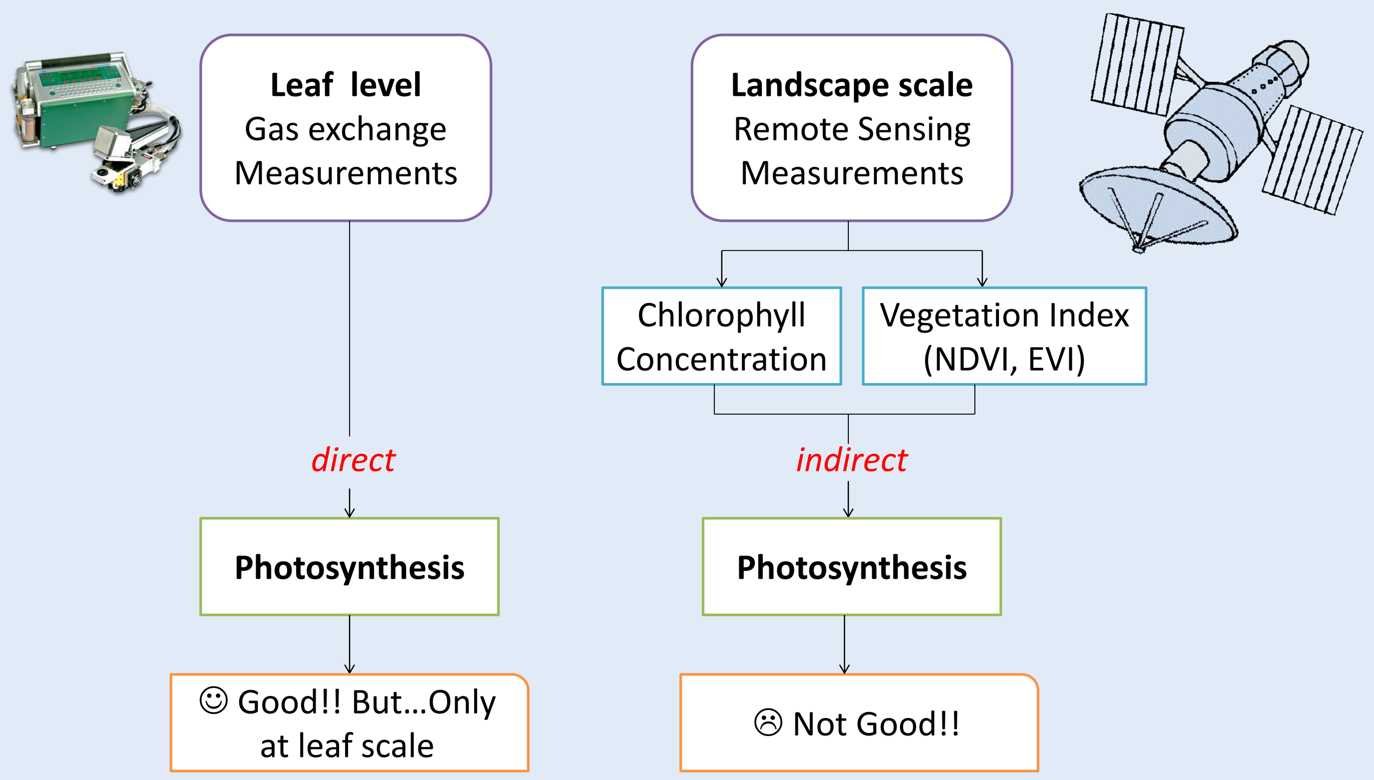
Steady-State Chlorophyll Fluorescence and Photosynthesis under Light and Drought Conditions in Camelina Plants

Maria Pilar Cendrero Mateo (mapilarcm@email.arizona.edu)[a,c], A. Elizabete Carmo-Silva[b], Michael E. Salvucci[b], M. Susan Moran[c], Shirley Papuga[a,d], Grey Nearing[e], and Mariano Hernandez[c].

[a] Soil Water and Environmental Science, University of Arizona - [b] USDA Arid-Land Agricultural Research Center - [c] USDA Southwest Watershed Research Center - [d] School of Natural Resources and the Environment, University of Arizona - [e] Hydrology and Water Resources, University of Arizona.

Introduction

Crop yield decreases when photosynthesis is limited by drought conditions. Yet farmers do not monitor crop photosynthesis because it is difficult to measure at the field scale in real time. Steady-state chlorophyll fluorescence (Fs) can be used at the field level as an indirect measure of photosynthetic activity in both healthy and physiologically-perturbed vegetation. In addition, Fs can be measured by satellite-based sensors on a regular basis over large agricultural regions.



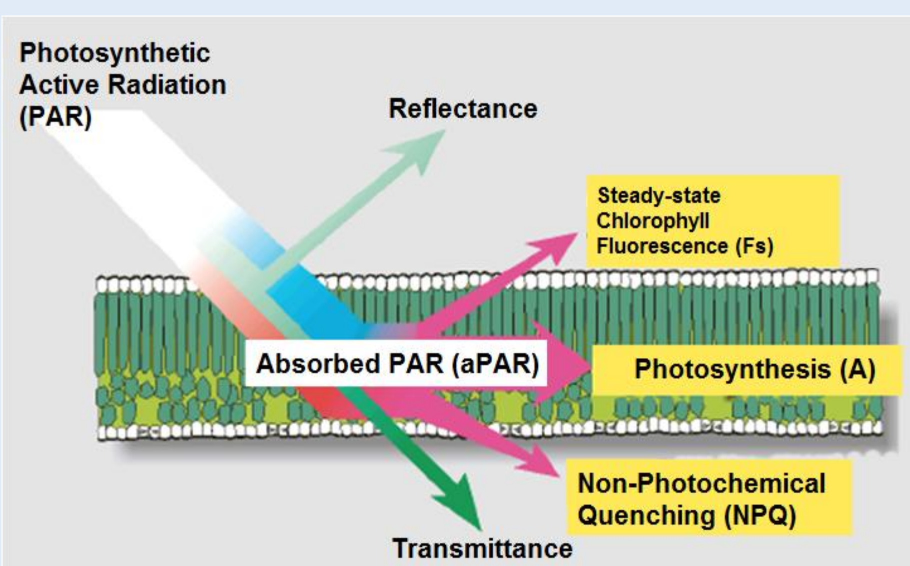
We need a good estimate of photosynthesis at landscape scale!!

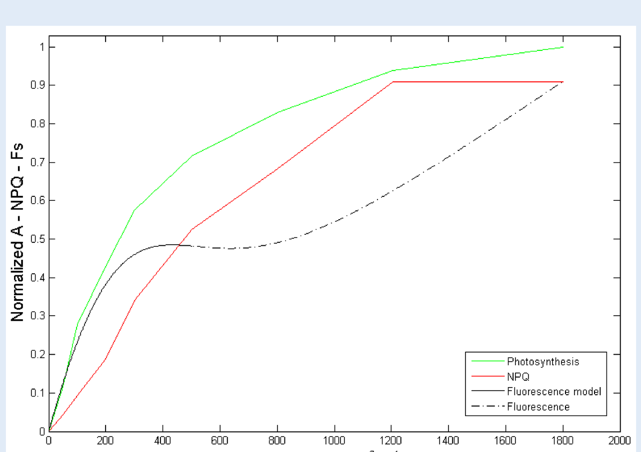
We think that answer lies in: **CHLOROPHYLL FLUORESCENCE,** which we can measure using gas exchange instruments and we will be able to measure by **satellite**.

The **F**luorescence **EX**plorer (**FLEX**) is the first mission proposing to launch a satellite for the global monitoring of steady-state chlorophyll fluorescence (Fs) in terrestrial vegetation.

Steady-state Chlorophyll fluorescence (Fs)

It is a **protection mechanism** for plants to **dissipate the excess energy** in the photosynthesis process. **Fs** occurs in **competition** with **Non-Photochemical Quenching (NPQ)** or **heat dissipation**, which is the other pathway of energy de-excitation, and the **photosynthesis itself**. Therefore, any increase in the efficiency of one process will result in a decrease in the yield of the other two. By measuring the yield of chlorophyll fluorescence, information about changes in the efficiency of photochemistry and heat dissipation can be gained (Maxwell and Johnson, 2000).





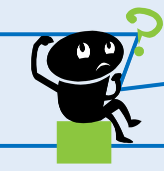
✓ The relationship between Photosynthesis and Fluorescence changes with aPAR.

Research questions?

What is the best PAR range to detect drought stress using Fs?

In order to achieve this objective we have 3 goals:

1. Understand how Fs behaves under different light conditions.
2. Understand how Fs behaves under different light and drought conditions.
3. Understand the relationship of Fs and Photosynthesis under different light and drought conditions.



Experiment

A) Camelina sativa (L.) plants were grown in:

- ✓a controlled-environment chamber
- ✓at 25/18°C
- ✓for a 12-h photoperiod
- ✓with irradiance of 500 μmol m^{-2} s^{-1}.

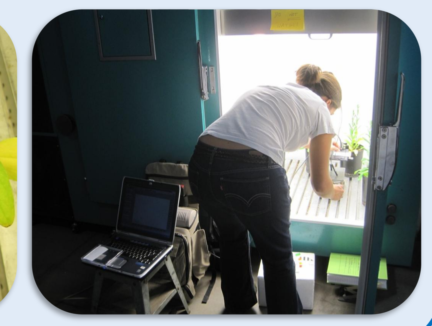
B) 16 pots containing 1 plant each were divided into 3 different treatments:

Day 1	Day 2
✓8 pots → control	✓8 pots → control
✓8 pots → drought	✓5 pots → drought
✓0 pots → re-water	✓3 pots → re-water

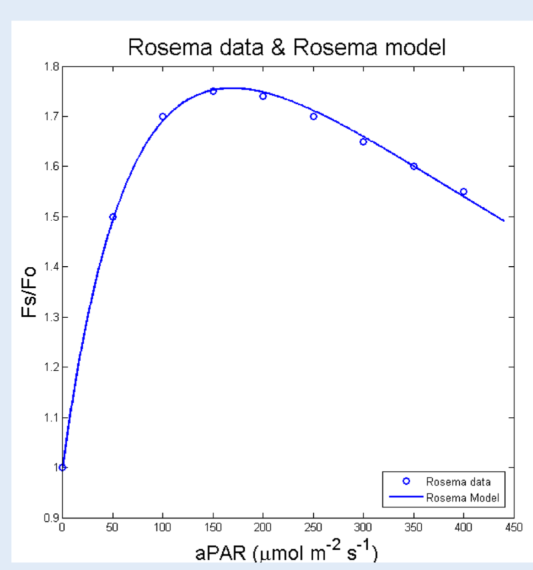
C) 2 types of measurements were made:

1. Gas-exchanges & chlorophyll fluorescence
2. Light response curve of A, Fs, and NPQ

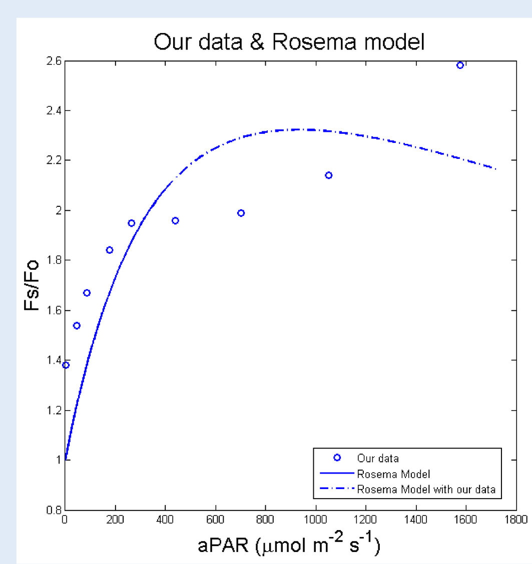
⇒ All parameters were measured with a LI-COR 6400.



1. Fs vs. light



Adapted from Rosema et al. (1998)



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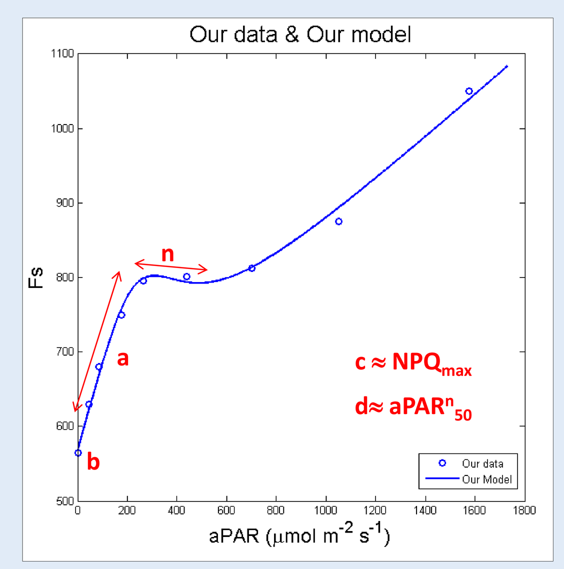


Rosema's model - Normalized Fs/Fo:

- ▪Valid for high light adapted plants
- ▪Our dataset ⇒ low light adapted plants
- ▪Does not describe our data set ⇒ Fs/Fo does not decrease when PAR>200

Our model coefficients :

- ▪**a**= fraction of aPAR that is converted to Fs.
- ▪**b**= Fs with no aPAR input.
- ▪**c** ≈ maximun NPQ realized at highest point on the light curve.
- ▪**d** ≈ aPAR level for which NPQ attains 50% of NPQ_{max}.
- ▪**n**= sigmoidicity of the curve.

Our model – Fs not normalized by Fo:

$$F_s = aPAR\left(a - \frac{c \cdot aPAR^n}{d + aPAR^n}\right) + b$$

▪ Combines **the linear growth** of fluorescence as a function of aPAR:

$$Fs_{initial} = a(aPAR) + b$$

▪ Logistic curve representing the plant's attempt to release heat in response to stress (ε)*:

$$\varepsilon = aPAR\left[\frac{c \cdot aPAR^n}{d + aPAR^n}\right]$$

*Serodio et al. (2011)

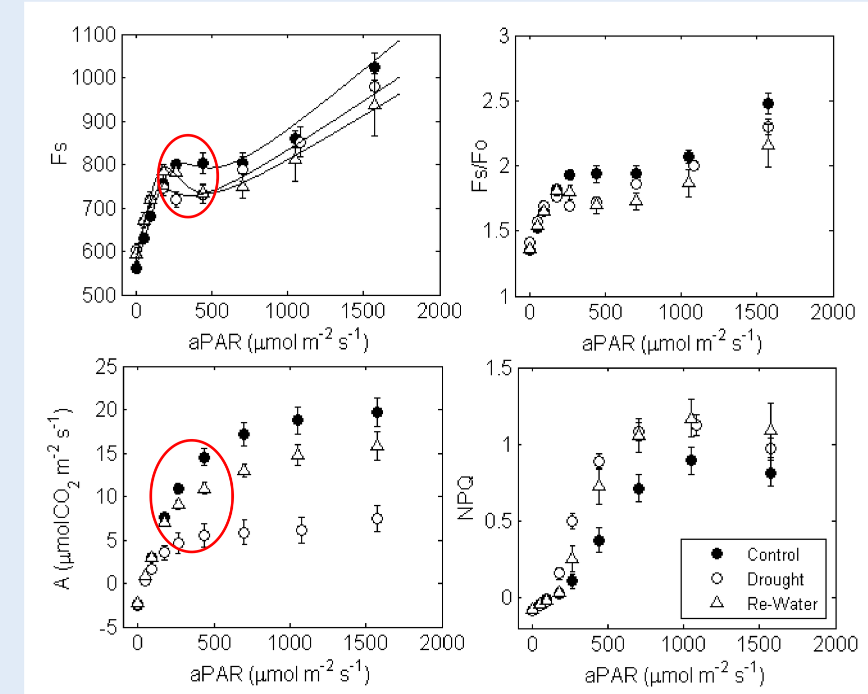
References

Maxwell, K. & G.N. Johnson. 2000. Chlorophyll fluorescence – a practical guide. Journal of Experiment Botany. 51:659-668.

Rosema, A., Snel, J.F.H., Zahn, H., Buurmeijere W.F., & Van Hove L.W.A. 1998. The Relation between Laser-Induced Chlorophyll Fluorescence and Photosynthesis, Remote Sens. Environ. 65:143-158.

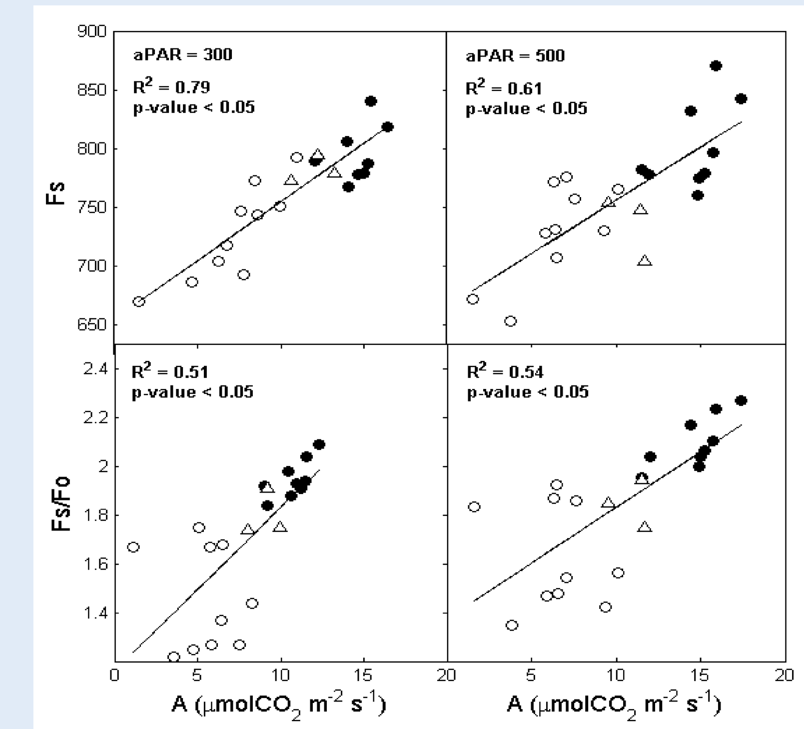
Serodio, J. & Lavaud J. 2011. A model describing the light response of the nonphotochemical quenching of chlorophyll fluorescence, Photosyn. Res. 108:61-76.

2. Fs vs. light and drought



- ▪New model is valid for all treatments
- ▪Fs/Fo ⇒ does not improve our results
- ▪Balance between Fs, A, and NPQ
- ▪PAR = 300 & 500 ⇒ **A** and **Fs** similar behavior (Control – Rewater – Drought)

3. Fs & A relationship

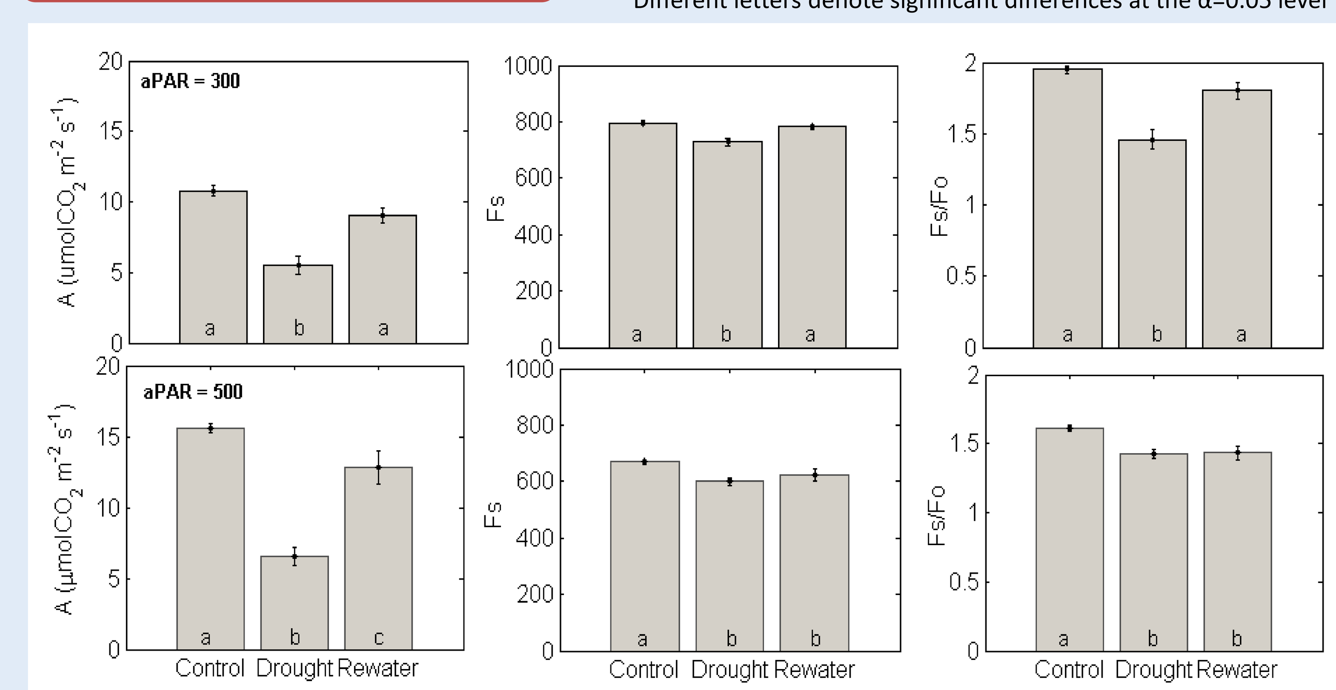


- ▪Fs/Fo ⇒ does not improve our results
- ▪Fs ⇒ positive correlated with Photosynthesis (A)
- ▪Positive and good correlation between Fs & A ⇒ aPAR when plants are light adapted.

Best PAR range to detect drought stress using Fs

PAR range = 300 – 500 μmol $m^{-2}s^{-1}$

Different letters denote significant differences at the α=0.05 level



- ▪Fs/Fo ⇒ does not improve our results
- ▪aPAR = 300 ⇒ A & Fs same results ⇒ It's the reason why the R^2 is so high.
- ▪aPAR = 500 ⇒ Only the "A" values are different, not Fs nor Fs/Fo.
- ▪aPAR = 500 ⇒ Fs is not able to detect plant recovery

Take home message

Under ambient light conditions ⇒ aPAR = 300 – 500 μmol $m^{-2}s^{-1}$:

a. We found a significant (P≤0.05) **positive correlation** between **Fs** and **Photosynthesis**.

b. Normalizing **Fs/Fo does not improve** our results.

c. **Fs is a good indicator of drought stress.**

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