On the use of different approaches based on photochemical reflectance index and surface temperature to monitor the water status of winter wheat in semi-arid regions

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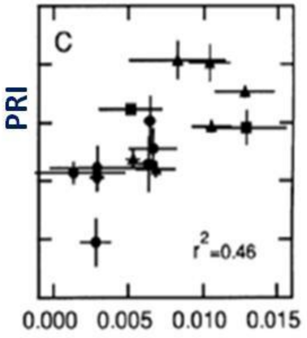
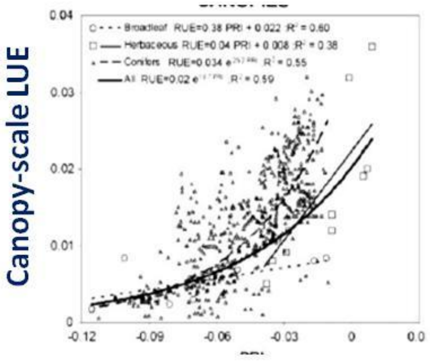
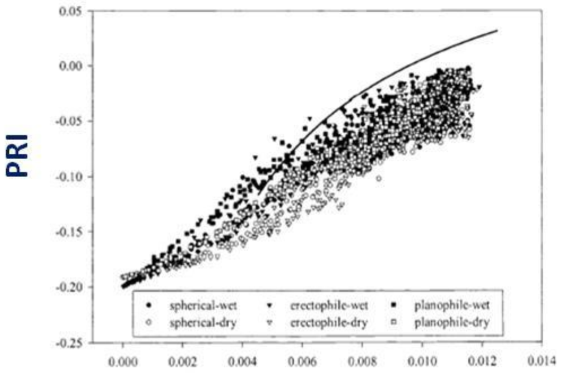
Context & Objectives



Leaf-scale LUE
Gamon *et al.*, 1997



PRI
Garbulsky *et al.*, 2008



Canopy-scale LUE
Barton & North, 2001

The Photochemical Reflectance Index (PRI) is based on the short term reversible xanthophyll pigment changes accompanying plant stress and therefore of the associated photosynthetic activities. Strong relationships between PRI and LUE were shown at leaf and canopy scales and over a wide range of species (Garbulsky et al., 2011). But very few previous works have explored the potential link with plant water status.

Photochemical Reflectance Index **(P.R.I.) (Gamon *et al.*, 1992)**

$$\mathbf{PRI = (R_{570} - R_{531}) / (R_{570} + R_{531})}$$

R_{531} is linked to leaf pigments (xanthophyll cycle)

theoretical range : $-1 < PRI < 1$

It is assumed that the calculated PRI0 integrates only the structural effect of the plant canopy. This effect can be subtracted from the PRI(midday), which includes the structure and functioning of vegetation.

PRIj = PRI0 - PRI(midday)
Magney et al. 2016

PRIj = PRIth - PRI(midday)
Soudani et al. 2014

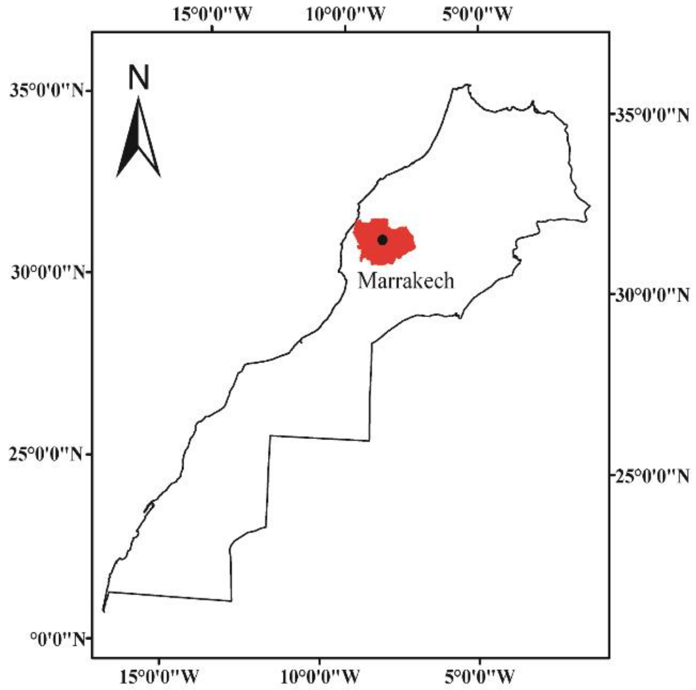
Study Area

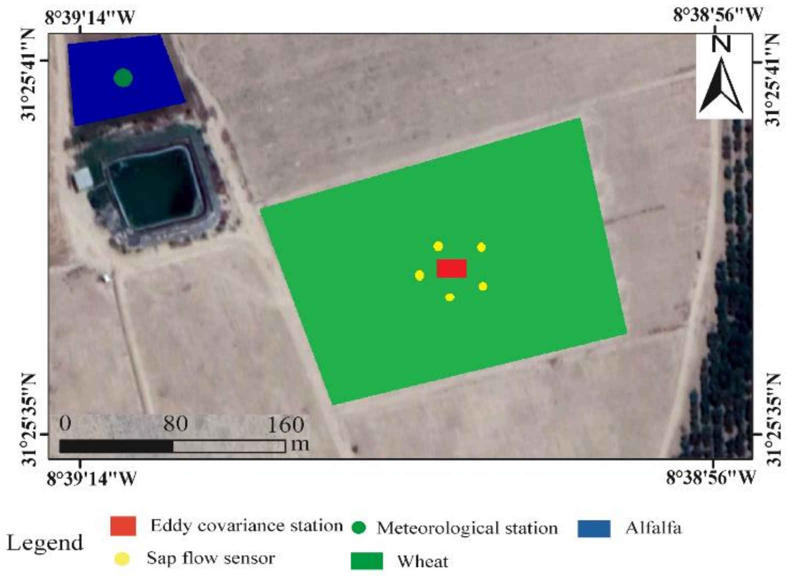
Chichaoua site in Marrakech regions

Irrigation mode : Drip-irrigation

- **The study site is located 70 km to the West of Marrakech (31°25'36.4"N, 8°39'05.9"W).**
- **Characterized:**
  - Low rainfall (250 mm / year).
  - Strong ET0 (1600 mm / year).
- **Irrigated wheat over 2016-2017 and 2017-2018 seasons.**
- **descriptive table:**

Season	2016-2017	2017-2018
Sowing date	11/27/2016	11/25/2017
crop type	wheat	Wheat + Organ
LAI max	2.6	4.1
Date of heading	03/03/2017	03/14/2018
Harvest date	05/16/2017	06/08/2018





Datasets (data acquisition : every 30 min)

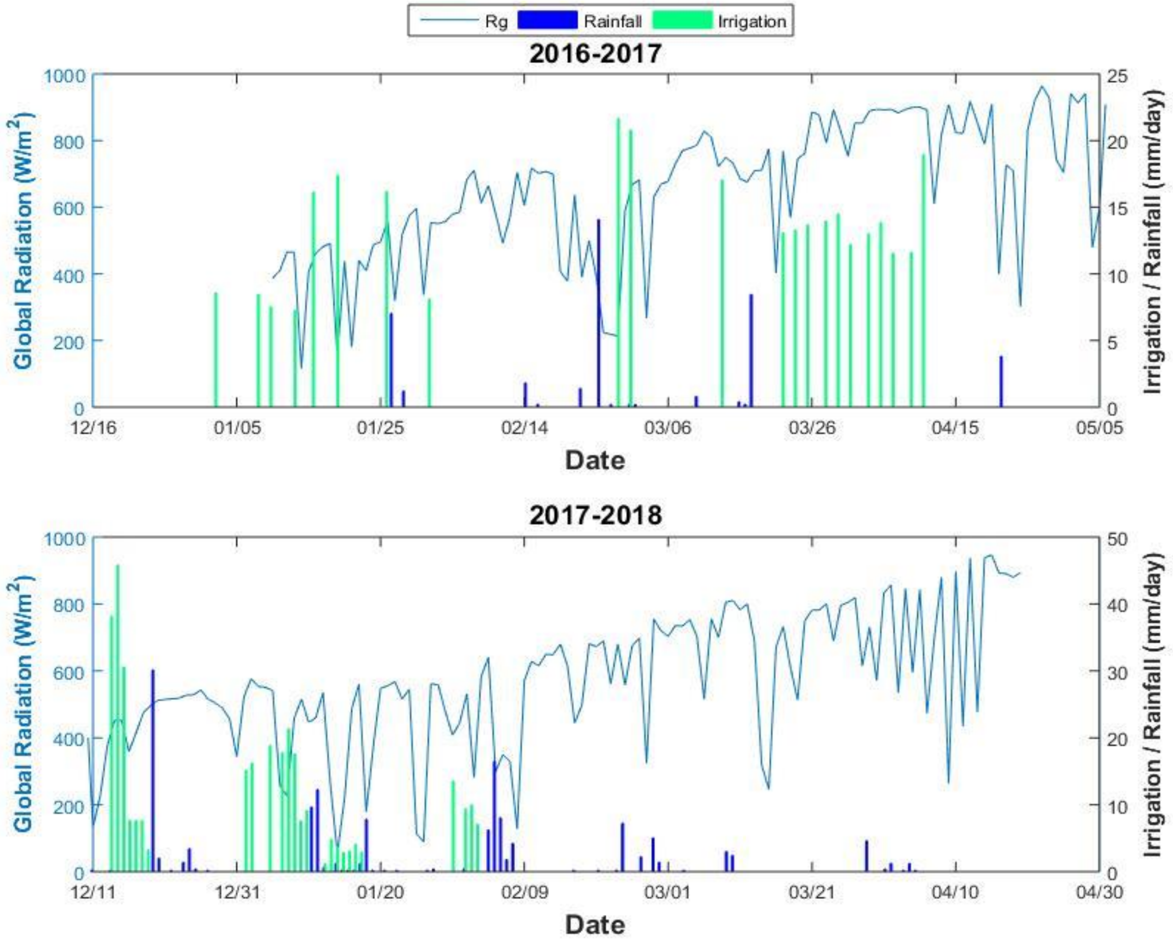
- **PRI sensors** (skye instruments).

- **Smart Field lysimeter** : Evapotranspiration and Transpiration rate.

- **Weather station** : Air Temperature, Global Radiation (Rg), VPD, Soil Water Content (top soil, 5 cm and 25 cm).

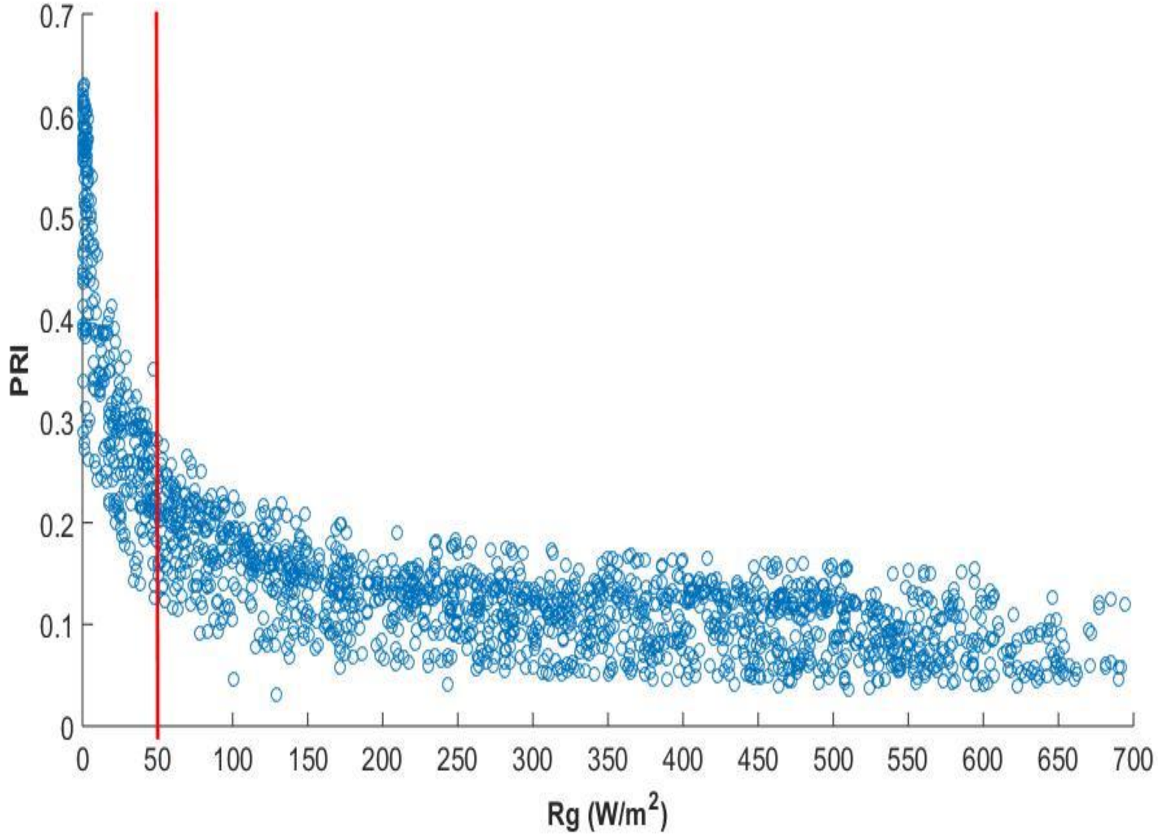
- **Sap Flow measurement** (Granier's method) : Transpiration rate.

- **IRT apogee** (Granier's method) : measure infrared radiation to determine surface temperature



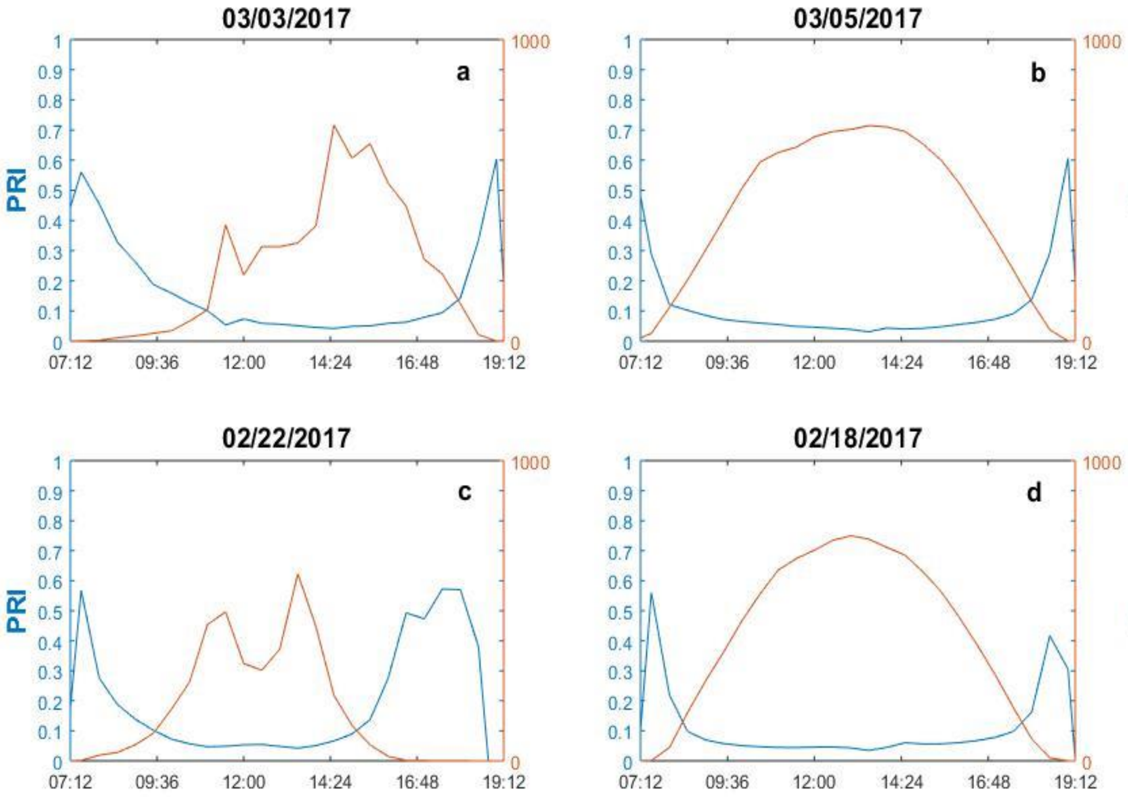
Figures of the dynamics of rainfall, irrigation and global radiation over the two seasons.

Preliminary Results



Variation between wheat morning PRI measurements and global radiation for the 2016-2017 season.

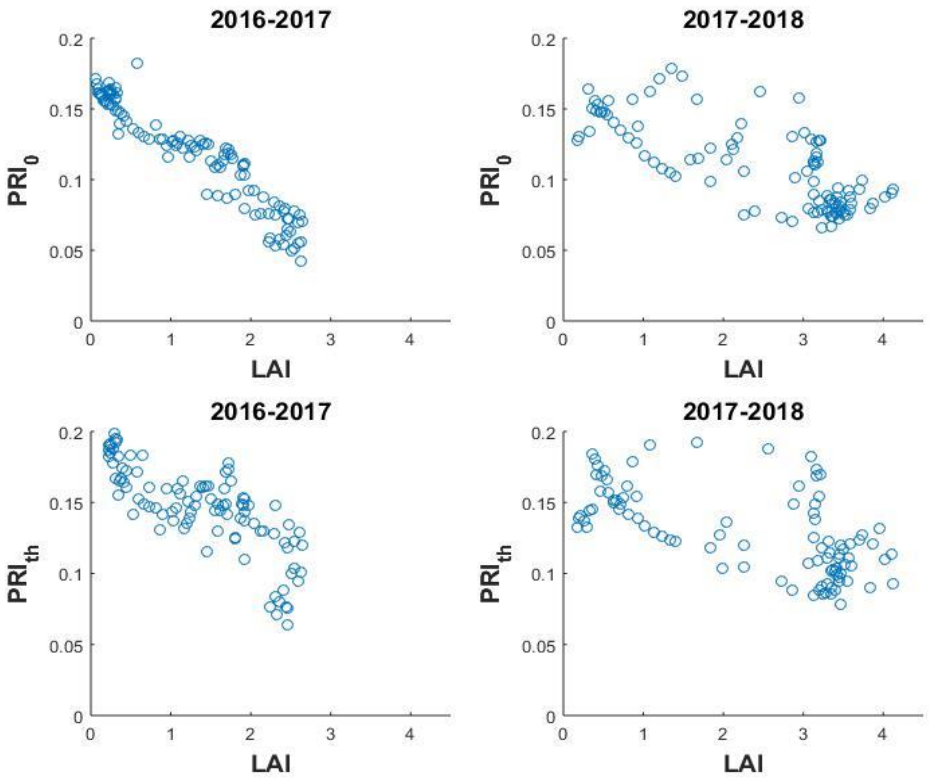
The impact of global radiation (Rg) for low values at the beginning of the day on the calculation of the PRI is clearly important. As can be seen, lower PRI values with a Rg threshold of 50 W/m2 show instability.



Evolution of the PRI signal and Rg for cloudy days (a and c) and for clear sunny days (b and d).

As can be seen, the disturbed Rg variation (cloudy days) in the morning and solar noon has a clear impact on the measured PRI signal (PRI_0 and PRI_{mid}).

Methods & Preliminary Results



Daily correlation between PRI0, PRIth and LAI during the 2016-2017 and 2017-2018 seasons.

The method of calculating PRI0 shows a better correlation with LAI which shows that it is the most suitable method, compared to PRIth, for estimating the structure part of the PRI signal on a winter wheat canopy.

Methods :

- The T_{LST} measured at the plot level allows us to calculate a normalized wheat surface temperature (T_{norm}) index that can tell us about the water status of the vegetation.

$$T_{norm} = \frac{T_{dry} - T_{mes}}{T_{dry} - T_{wet}}$$

Where T_{wet} and T_{dry} are the wheat surface temperature under extremely wet and dry conditions, respectively.

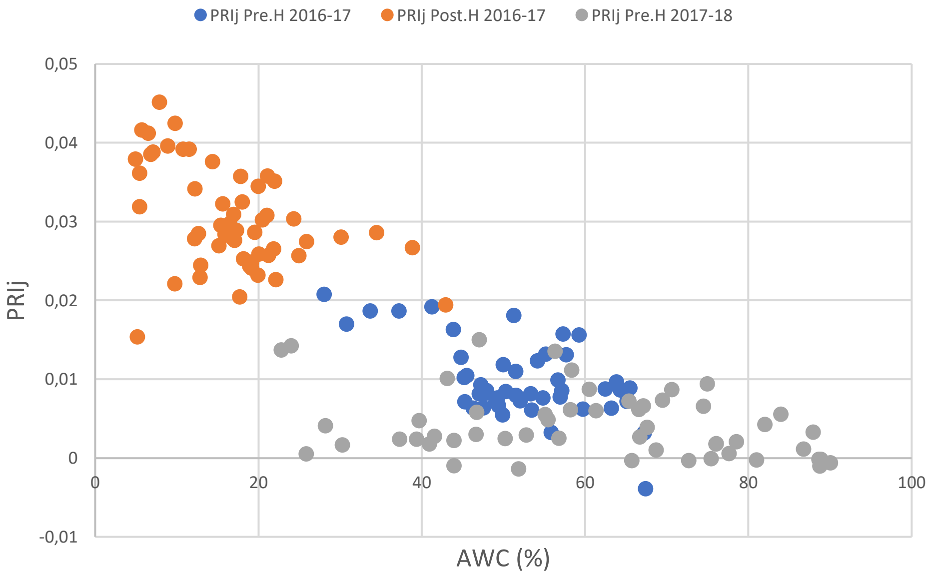
- The estimation of the potential PRI is based on a selection of days with irrigation and maximum radiation, which allows us to have daily values of the PRI_{mid} in the absence of water stress. The selection of these days is made using the criterion of available water content (AWC>=50%).

$$I - PRI = \frac{PRI_{pot} - PRI_{mid}}{PRI_{pot}}$$

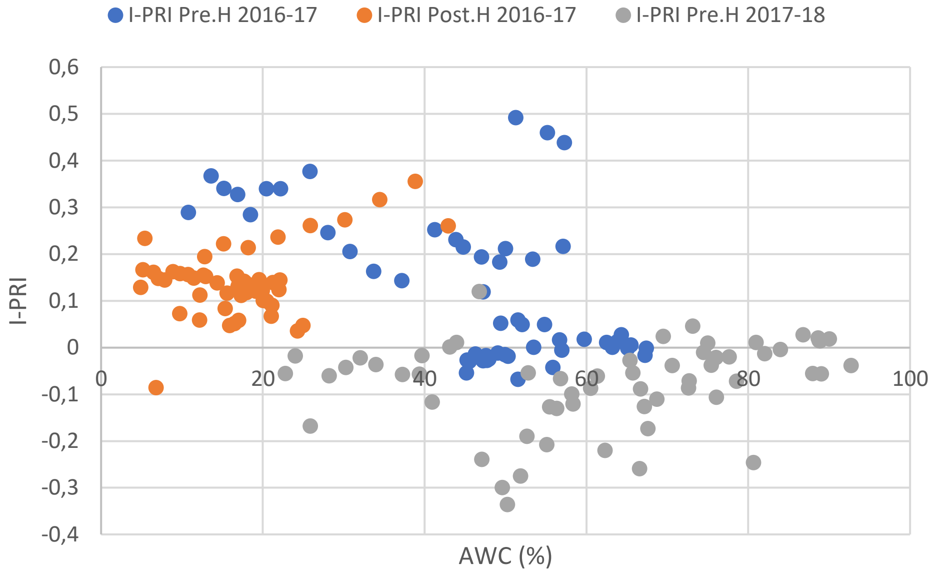
- The available water content (AWC) represents the maximum amount of water that the soil can contain and return to the roots to maintain plant life. The equation of the AWC is as follows:

$$AWC(\%) = \frac{(\theta_{5cm} - \theta_{wp}) * h_{5cm} + (\theta_{15cm} - \theta_{wp}) * h_{15cm} + (\theta_{25cm} - \theta_{wp}) * h_{25cm}}{(\theta_{fc} - \theta_{wp}) * (h_{5cm} + h_{15cm} + h_{25cm})} * 100$$

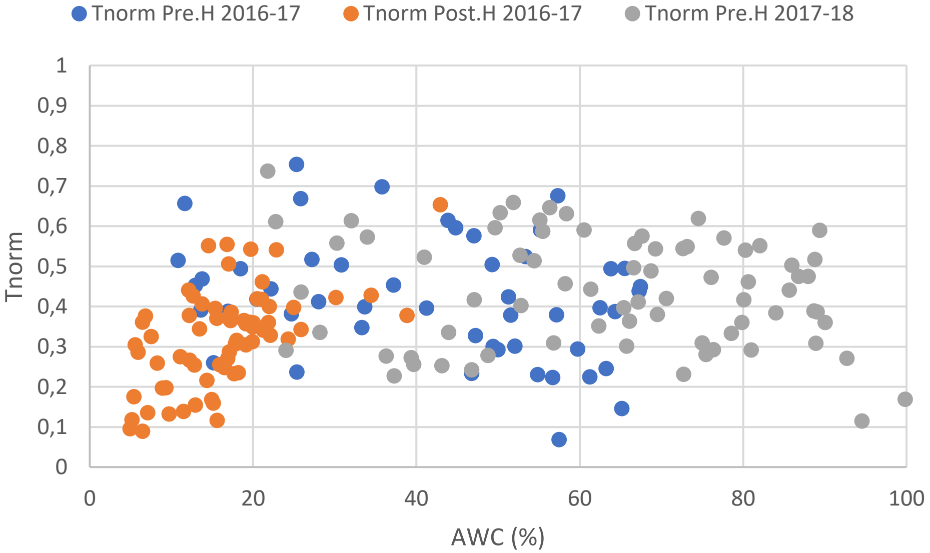
Results



Correlation between the PRIj stress index and the RU useful reserve in the soil during the 2016-17 season and before heading for the 2017-18 season



Correlation between the I-PRI stress index and the AWC during the 2016-17 season and before heading for the 2017-18 season.



Correlation between the Tnorm stress index and the AWC during the 2016-17 season and before heading for the 2017-18 season.

Conclusion and perspectives

- Strong effect of the PRI0 determination method on the PRIj's potential for characterizing the water status of the cover (strong effect of Rg on the PRI0 signal).

- It was demonstrated that LAI clearly impacts season-wide PRI signal measurements, particularly for wheat, which is an annual crop.

- the PRIj index that we were able to develop shows a total independence to the structural effects related to LAI and reflects the level of water stress that the wheat plot faced during the whole experiment. This allowed us to obtain a coefficient of determination between the PRIj and the AWC of 0.71.

- This allowed us to demonstrate that the Tnorm is a late water stress index that responds to water shortage only below a threshold of 20% AWC.

- Comparing the PRIj index with the Tnorm index, it was clear that the PRIj is an early water stress index and that it provides us with information on the state of the vegetation cover at all stages of wheat development.

Need to explore:

- ➢ Higher acquisition frequency of Rg & PRI (5 instead of 30 minutes) for better determination of PRI0.
- ➢ Use another index based on a potential value of the expected PRI in the absence of water stress.

Thank you for your attention