DEVELOPMENT OF A LOW-COST PORTABLE PAR DEVICE FOR CROP MANAGEMENT

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In the context of climate change and innovative agroecological practices, it is essential to have precise monitoring of crop growth to ensure rapid action in case of problems. Plant growth depends on the biomass accumulated by photosynthesis that requires as energy source, photosynthetically active radiation (PAR). This variable is essential to study plant phenology and for ecophysiological models allowing prediction of biomass with daily determination of dry matter accumulated (STICS: Brisson et al., 2003; APSIM: Keating et al., 2003; AZODYN: Jeuffroy and Recous, 1999). Thus, because of field microclimate, PAR sensors need to be placed close to the field. However, commercial measuring instruments consist of a data logger and one or more sensors and are too expensive. In addition, a PAR sensor is rarely installed on automatic weather stations. The objective of this study is to propose an innovative device development, a low-cost miniaturized solution which is robust and energy autonomous and that can easily be moved from one field to another.
An engineering solution to design, implement and calibrate a PAR measurement device (SOLEM PAR/LE) combined with an open-source electronic platform (Arduino) is presented. The device is named PARADe (PAR Acquisition Device). The PAR sensor was calibrated by comparison with a calibrated sensor (PQS1 PAR Quantum Sensor, Kipp & Zonen) and an industry standard data-logger (CR1000 Campbell Scientific).

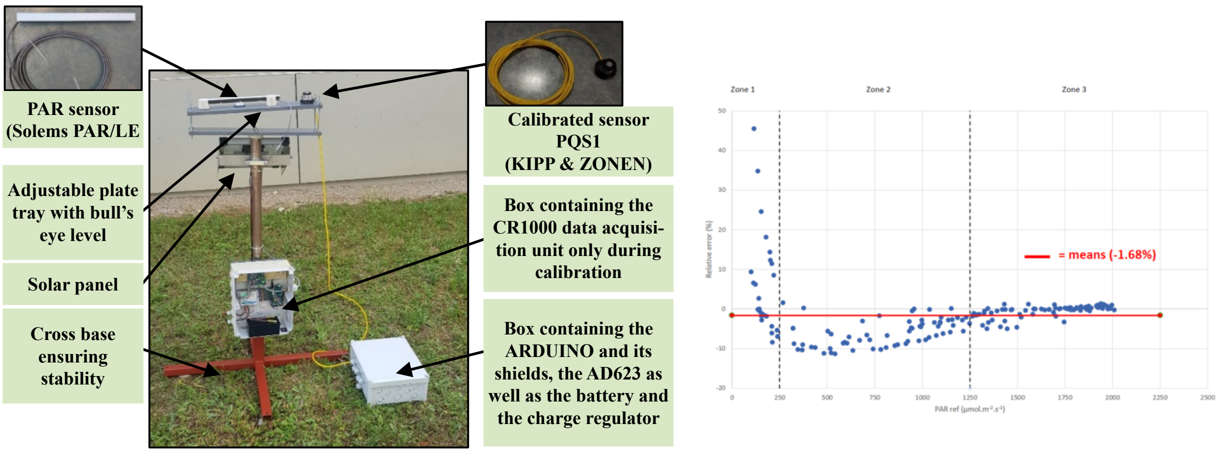

Figure 1: Left: Portable PAR device, Right: Relative error as a function of actual PAR.

The ARDUINO card records the PAR sensor voltage through an AD623 amplification (rail-to-rail amplifier) every five seconds in its internal memory. After 60 values (i.e. 5 minutes), it calculates the average of the voltage values and writes it to the microSD card. The average of the 60 measurements is recorded every 5 minutes to reduce the variability from the ARDUINO and the sunshine conditions. To make the calibration curve relating the output voltage of the PARADe acquisition chain to the radiation, it is necessary to place the calibrated sensor close to the sensor to be calibrated (Figure 1, left). To test good repeatability of the device, measurements were taken at different days or times of the day, in different places, in the shade, and in the sun. To verify the accuracy of PARADe measurements, a relative error (RE) profile was carried out.

This profile is a graph showing RE (defined by Eq. 1) as a function of the actual PAR.

$$\text{Relative error} = ((PAR_{device} - PAR_{ref}))/PAR_{ref}*100 \quad (1)$$

With two different PAR values: the amount of PAR_{ref} which is determined using the calibrated sensor connected to the CR1000 data logger and that of the PAR_{device} obtained by the calibration equation of PARADe.
The graph in Figure 1 (right) represents this relative error profile of the PARADe device. On average, the portable device with the ARDUINO card has a relative error of -1.68%. In this figure, the strong errors observed at low PAR values are ultimately inherent due to the shape of the sensor and do not defeat the acquisition chain. Following Standard ISO 9847, it emerges that in practice the radiation measurements for which the solar altitude angle is less than 20 ° (at sunrise sun and sunset) are excluded. It is due to the poor quality of response to the radiation of this type of rectilinear sensor (Standard ISO 9847: 1992). The calibration curve can therefore be kept.
Compared to other portable devices available (Barnard et al., 2014), the PARADe device appears to be as effective or even superior for high PAR radiation. These results make its use operational. These PAR measurements can then be used as input parameters for ecophysiological models. In perspective, a smartphone, a digital tablet or a laptop could be the interface with the device via a Bluetooth or Wi-Fi connection.

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