Remote monitoring of ponding water levels in rice paddies using an open-IoT device: SmartWT

Pietro Mascherpa [1], Michele Rienzner [1], Darya Tkachenko [1], Fabio Brandalese, Roberto Garza, Claudio Gandolfi [1], Arianna Facchi [1]

[1] Department of Agricultural and Environmental Sciences - Production, Landscape, Agroenergy (DiSAA), Università degli Studi di Milano, via Celoria 2, 20133, Milano, Italy

pietro.mascherpa@unimi.it

1- General Context

Rice in Italy is cultivated traditionally using flooding methods.

Climate change and competition for water resources have led to water scarcity.

The EU has introduced stringent limits on gas emissions and heavy metals content in grain.

Alternate Wetting and Drying (AWD) technique reduces water use, gas emissions and decreases grain Ar accumulation.

AWD is based on alternating flooding and drying conditions guided by the water level measured in a Water Tube (WT)

WT is inserted into the soil to monitor the ponding water level above and below the soil surface.

A new flooding event occurs when the water level below the soil surface drops below a certain threshold (e.g. -25 cm).

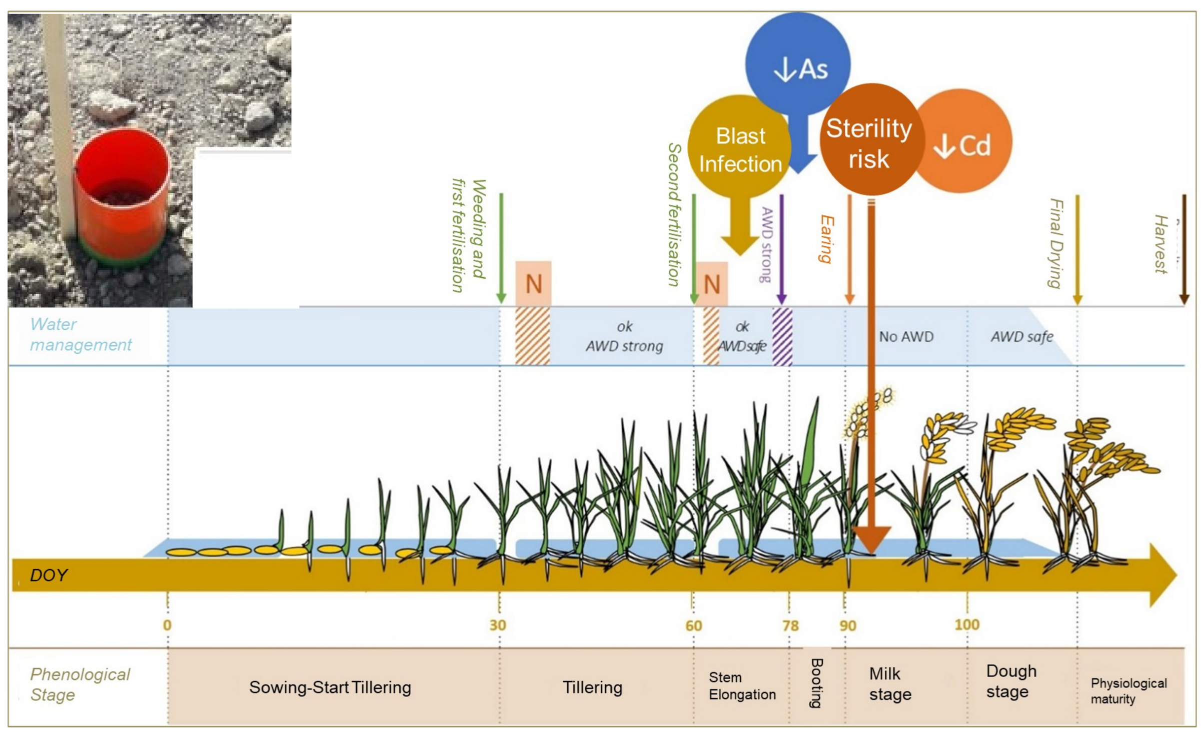


Fig. 1: Application of AWD during the rice growth, from the beginning of the tillering phase until panicle initiation (source: ENR – Ente Nazionale Risi).

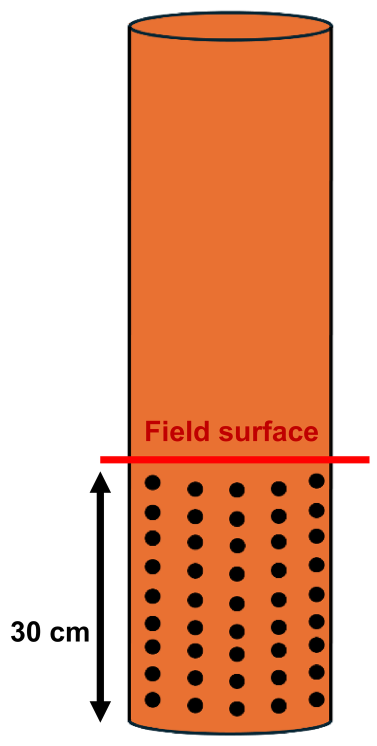


Fig.2: Water tube schematic.

2- Motivation for the development of SMART-WT

Manual WT monitoring encounters several problems

Difficult access conditions of puddy fields.

Time-consuming operations

A tool for continuous remote monitoring is needed.

3- SmartWT: remote monitoring of field water level

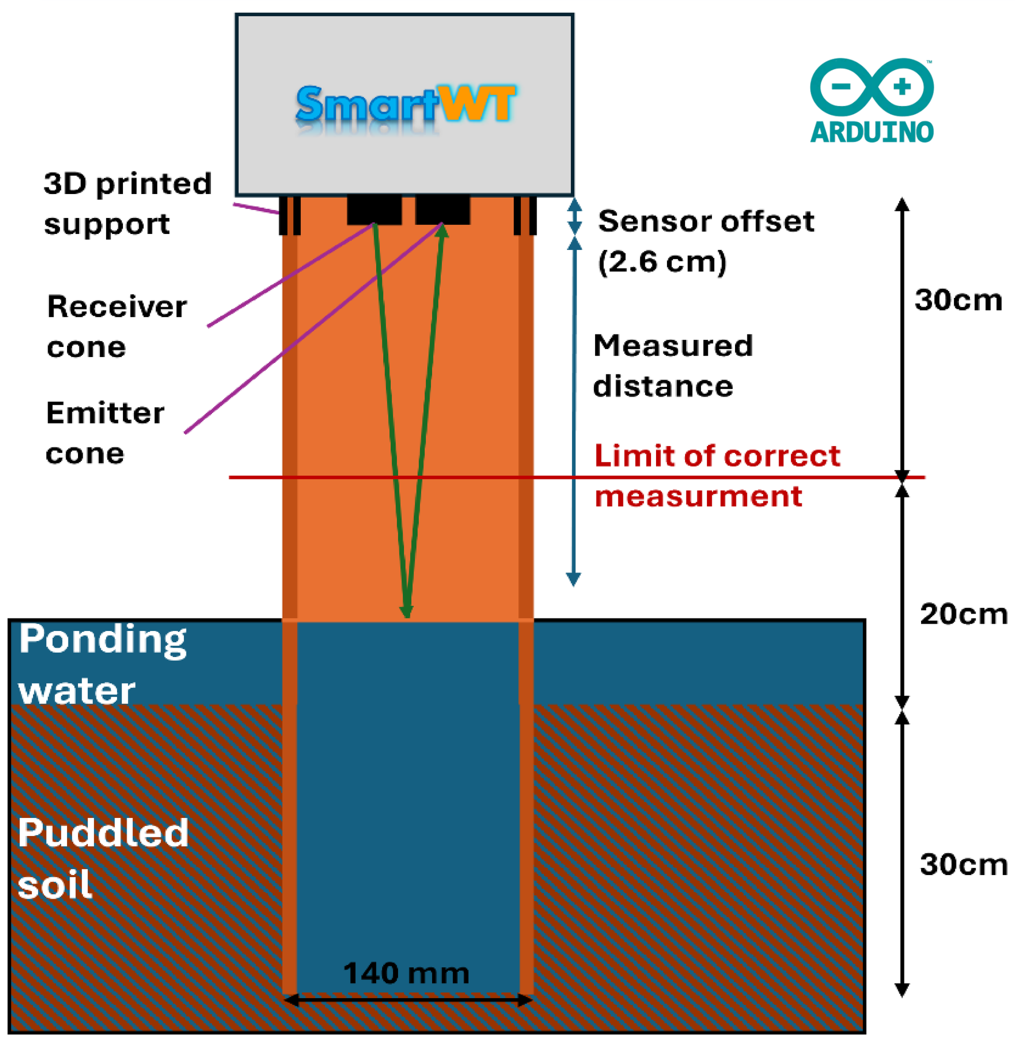


Fig. 3: SmartWT installation schematic. The SmartWT is installed on top of the WT and measures the distance from the ponding water. A minimum distance between the sensor and the water is crucial for accurate measurements.

- Based on Open source Hardware and software.
- Waterproof ultrasonic sensor for measuring distance, not in contact with water.
- GSM module to send data to an online server for easy and real-time monitoring.
- Efficient battery management ensures long battery life (2-3 months).

Advantages

Online Server ThinkSpeak for real-time visualisation and data storage/export.

Arduino-based, highly customizable for different applications

Narrow-band IOT GSM connection to send data cheaply and everywhere

Cost-effective solution: around 200€

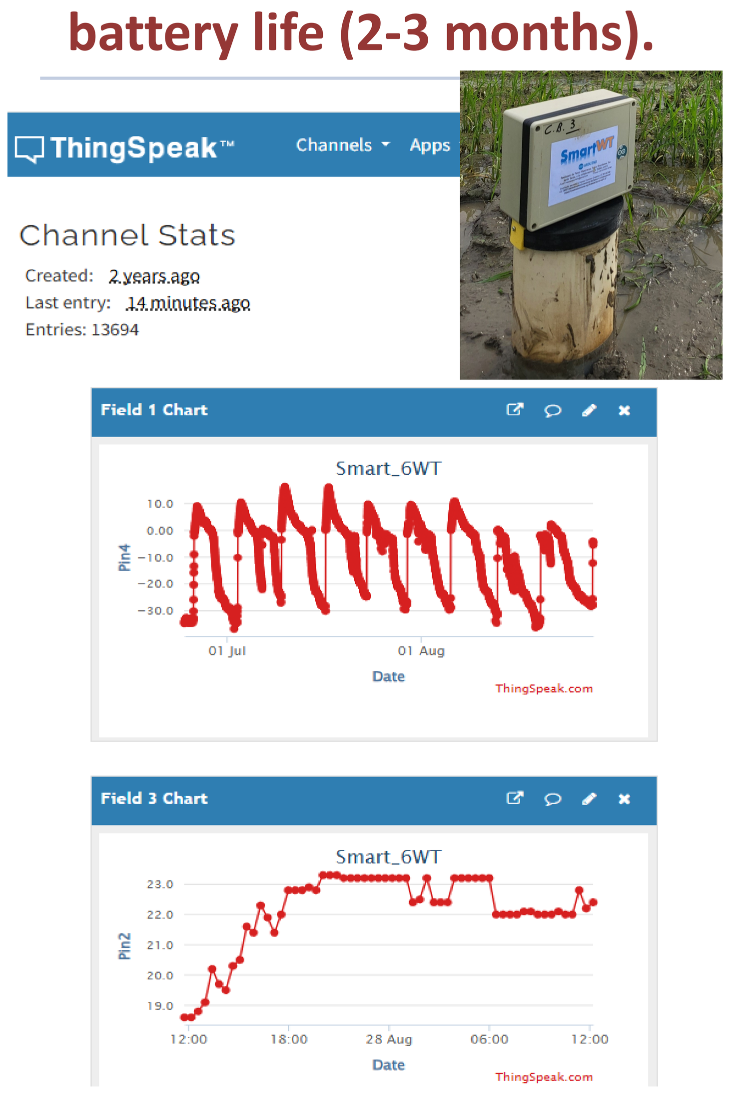


Fig. 4: ThingSpeak visualization page. Here, users can observe data from the field, customise the view and export data..

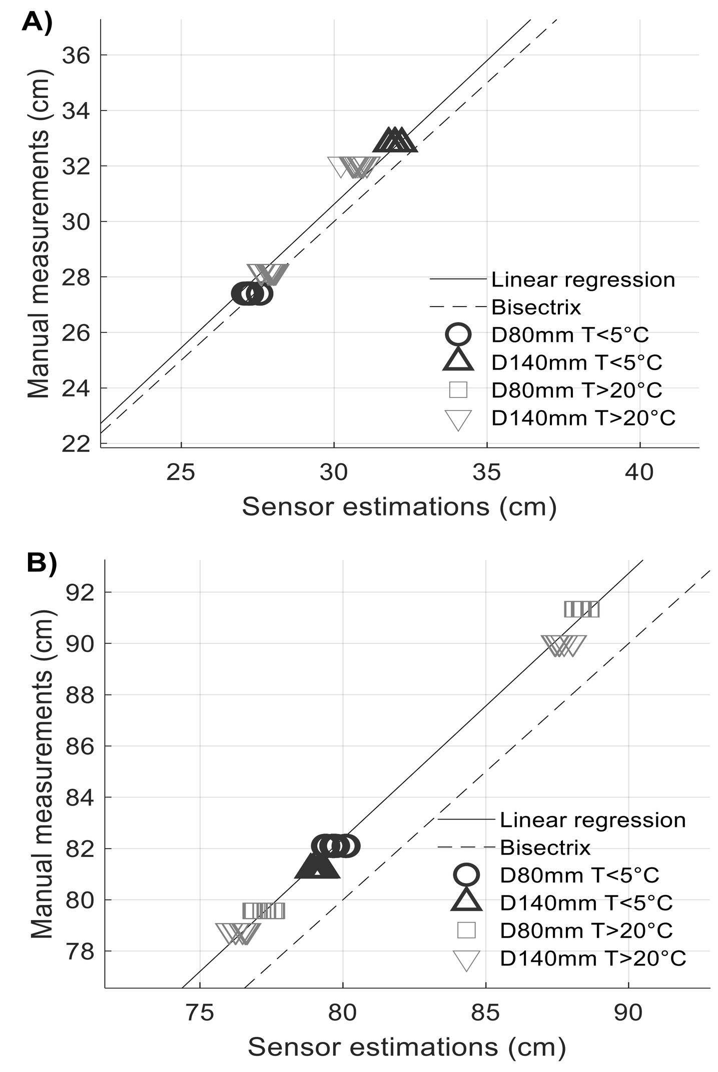
4- Accuracy assessment and calibration

The device's accuracy was assessed through comparison between SmartWT data and manual measurements, considering different pipe diameters, environmental temperatures and water levels. Main findings were:

- A minimum distance of 25-30 cm between the sensor and the maximum water level is needed for correct readings.
- Pipe size (over 100 mm) doesn't affect the device's measurements.
- Changes in air temperature slightly affect measurements as sound speed varies. Fig. 6 (C) shows the errors if a constant speed of sound is used.
- Fig 6 (A and B) shows a strong linear relationship between manual and SmartWT measurements, but the lines differ from the bisectors of the quadrant. A correction formula was found using mixed-effect models:

$$\widehat{Hfinal} = 1.028 \cdot H_{Measured}$$

Final accuracy: 1 cm without temperature sensor, a few mm adding a temperature sensor.



C)

T (°C)	Distance (cm) 30	50	80
14	30.5 (0.52)	50.9 (0.86)	81.4 (1.38)
20	30.2 (0.20)	50.3 (0.34)	80.5 (0.54)
30	29.7 (-0.30)	49.5 (-0.50)	79.2 (-0.80)
40	29.2 (-0.78)	48.7 (-1.29)	77.9 (-2.07)

Fig.6. Panel (A) shows 'small' distances between the sensor and the water table, whille Panel (B) shows 'long' distances. The colors and symbols refer to different experiments. The linear regression (continuous line) and bisector of the first quadrant (dotted line) are illustrated. Panel (C) shows the values obtained by the device using a reference temperature of 24° C instead of the actual temperature. Error (difference between estimated and true distances, cm) is reported in brackets.

5- Field Data Acquisition

SmartWT was tested in 9 productive rice fields. It monitors the distance at 10-minute intervals (customisable time) and makes a comparison with the last measurement sent. If the measurements differ by more than a certain value (also customisable), the measurement will be sent to ThingSpeak; otherwise, the data will not be sent. However, after a certain amount of time (also customisable), the data will be sent to the server. This procedure enables real-time monitoring without excessive energy consumption.

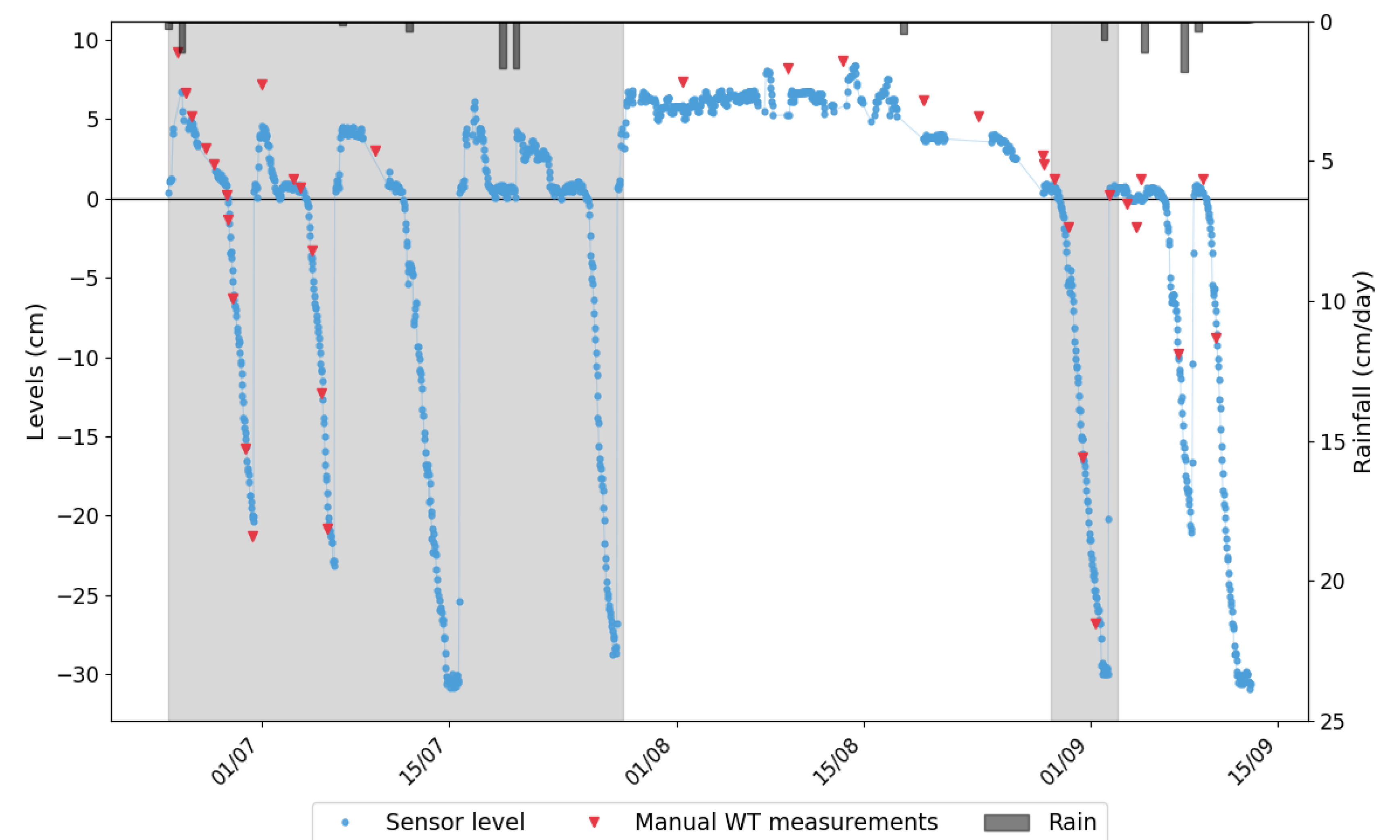


Fig. 5: This time series collected during the 2024 rice-growing season showing the ponding water level measured by the sensor (blue dots), manual measurements (red triangles) and daily rainfall (grey bars). The light grey shaded areas indicate the AWD management periods, while continuous flooding occurred during the remaining time, up until 6 September, when the final drying phase began.

5- Conclusions

The device's accuracy has been demonstrated to be adequate for monitoring rice fields ponding water level.

The field tests demonstrated that the sensor tolerates the difficult conditions characterising rice paddies.

SmartWT is an accurate, efficient and cost-effective solution for monitoring water levels in rice fields.

Acknowledgements

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