Proximal Gamma Ray Spectroscopy for monitoring Soil Water Content in vineyards

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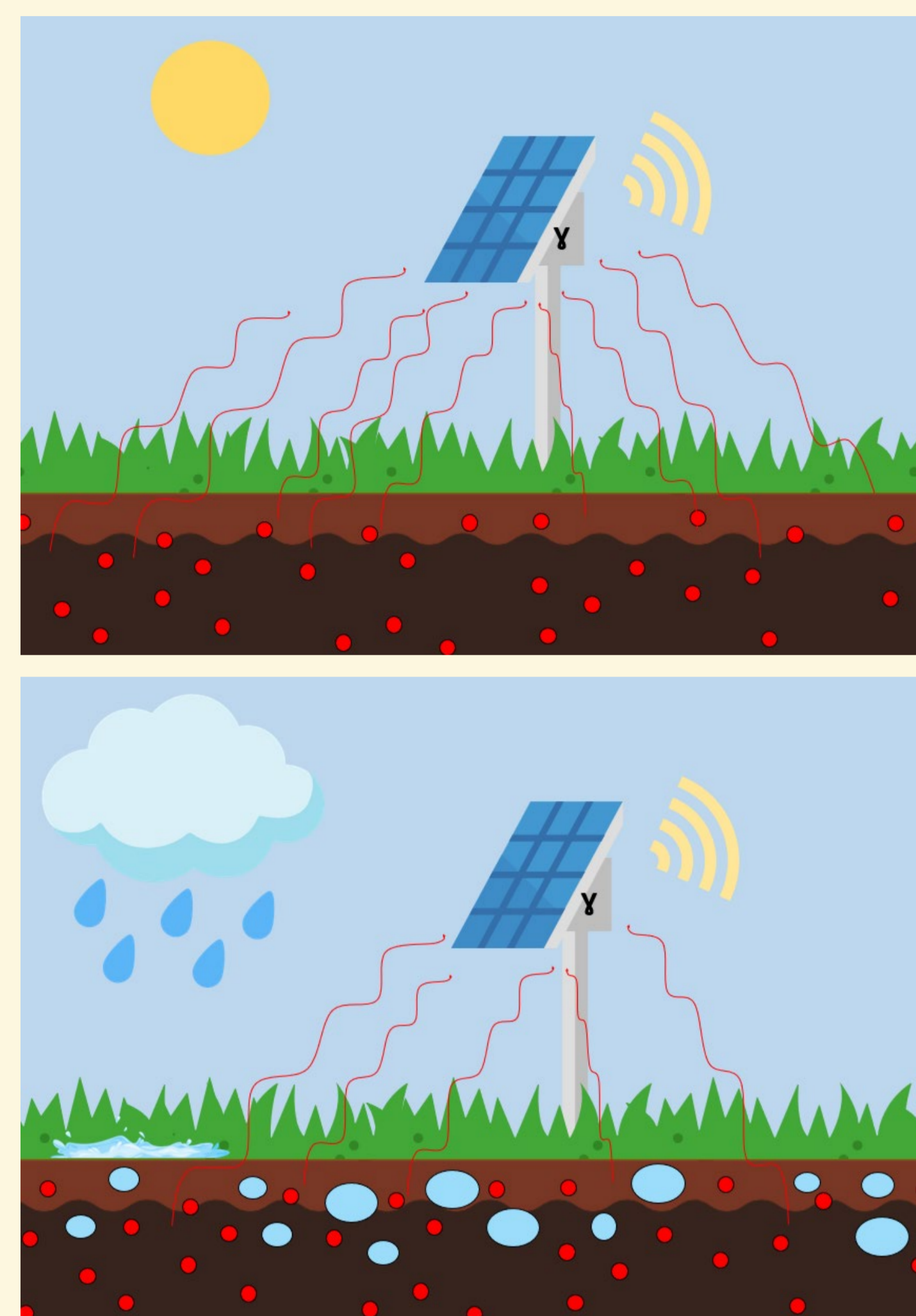
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Motivation and method

❖ **Soil Water Content** (SWC) is a key information in **precision agriculture** for obtaining high levels of efficiency and health of crops, while **reducing water consumption**.

❖ In the case of **vineyards**, due to the recent extreme temperature fluctuations, the knowledge of the SWC of the entire field becomes crucial to allow a **timely intervention** with emergency irrigation to preserve plant health.

❖ **Proximal Gamma Ray Spectroscopy** (PGRS) technique can provide field-scale, non-invasive and real-time measurements of gravimetric **SWC**.

❖ PGRS is based on a **gamma-ray detector**, continuously recording photons resulting from the **radioactive decay of ^{40}K** in the soil, which are **attenuated** proportionally based on the amount of stored water.

Experimental setup and calibration

❖ The experimental setup comprises a **gamma spectrometer** powered by **photovoltaic panels**, which provides data at intervals of **3 hours**.

❖ The detector, positioned at a height of **2.3 meters**, has a **footprint of 260 m²** in a **Montalcino** (Siena, Italy) vineyard.
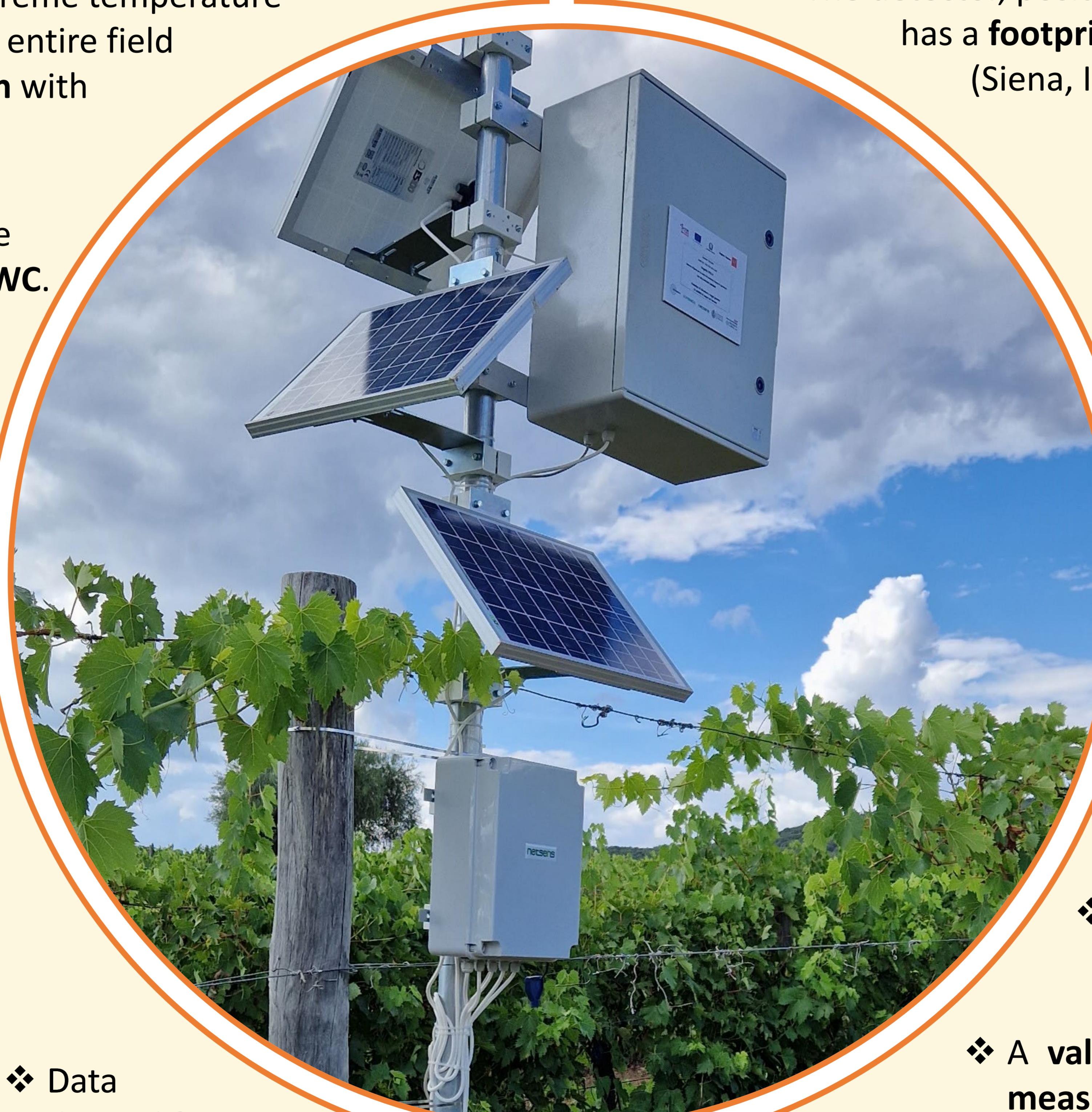
❖ The **SWC value** $\left[\frac{\text{kg}}{\text{kg}}\right]$ is determined from the **Counts Per Second (CPS)** using the formula:

$$SWC\,(t) = \frac{A}{CPS\,(t)} + B$$

❖ The parameters $A = 3.8 \pm 0.1$ [CPS] and $B = 15.1 \pm 2.5 \left[\frac{\text{kg}}{\text{kg}}\right]$ are obtained through a **one-for-all** calibration using **gravimetric** SWC measurement by collecting **9 soil samples** within the detector's field of view.

Analysis and results
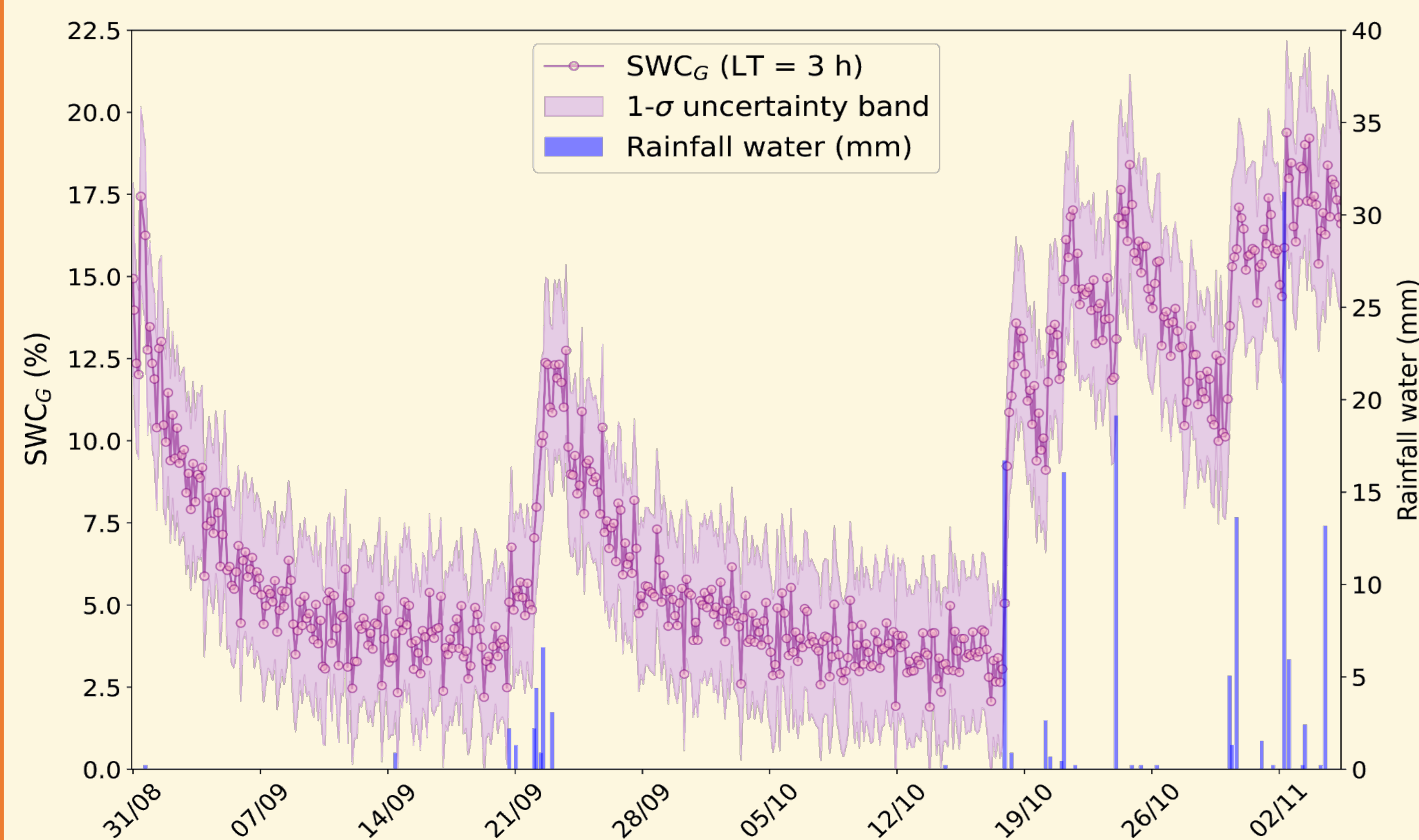
❖ Data derived from the SWC formula enables the reconstruction of the **SWC temporal profile** of the field under study and offers insights when overlaid with **rainfall event data** derived from an in-situ **rain gauge**.

Conclusions

❖ **Automatic spectral analysis** has been developed to **calibrate** and **extract net counts** in the peak of ^{40}K.

❖ The combination of **instrumental setup** and **analysis algorithm** of gamma-ray spectra reliably reconstructs **the temporal evolution of SWC** in the studied field.

❖ A **validation** procedure compared PGRS measurements with **direct gravimetric measurements** on soil samples. The **1-σ agreement** confirms PGRS effectiveness in quantifying SWC in cultivated fields.

❖ This research demonstrates the **reliability** over an **8-month period**, as well as the **precision** and **accuracy** of the PGRS method in estimating SWC on **large footprints** (~ 260 m²) in **real-time**, even in **vineyard** contexts.

Validation		
DATE	SWC$_{PGRS}$ (%)	SWC$_{G}$(%)
04/10/23	5.8 ± 2.5	9.0 ± 1.5
31/01/24	10.5 ± 2.6	11.9 ± 1.8

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