A Cost-Effective Portable Multiband Spectrophotometer for Precision Agriculture

F.J. Fernández-Alonso[1], Z. Hernández[2], V. Torres-Costa[1,2]

[1] Department of Applied Physics and Nicolás Cabrera Institute. Universidad Autónoma de Madrid, 28049 Madrid, Spain

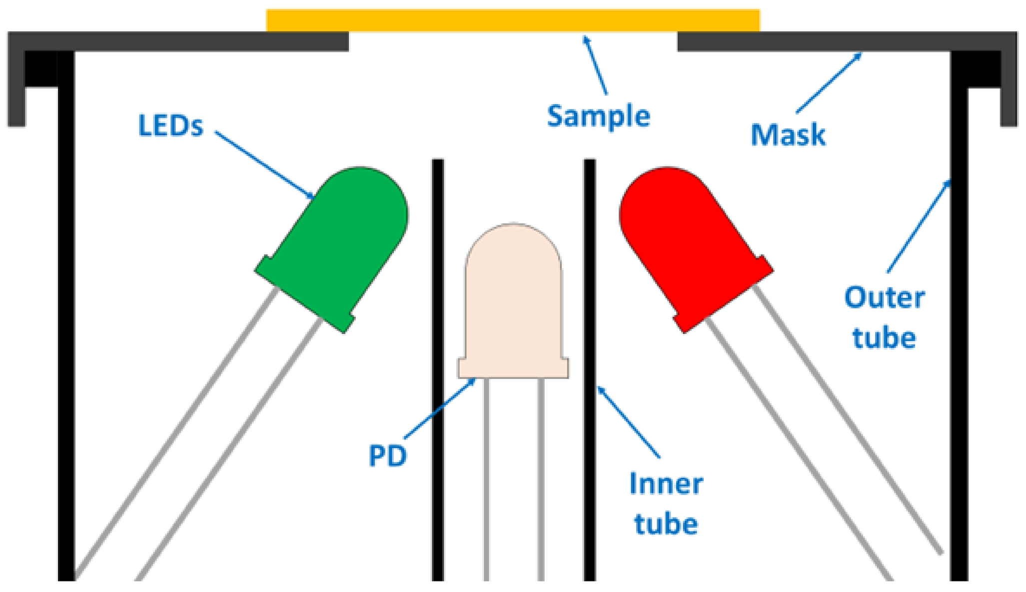
[2] Copernicus-UAM Remote Sensing Laboratory, Universidad Autónoma de Madrid, 28049 Madrid, Spain

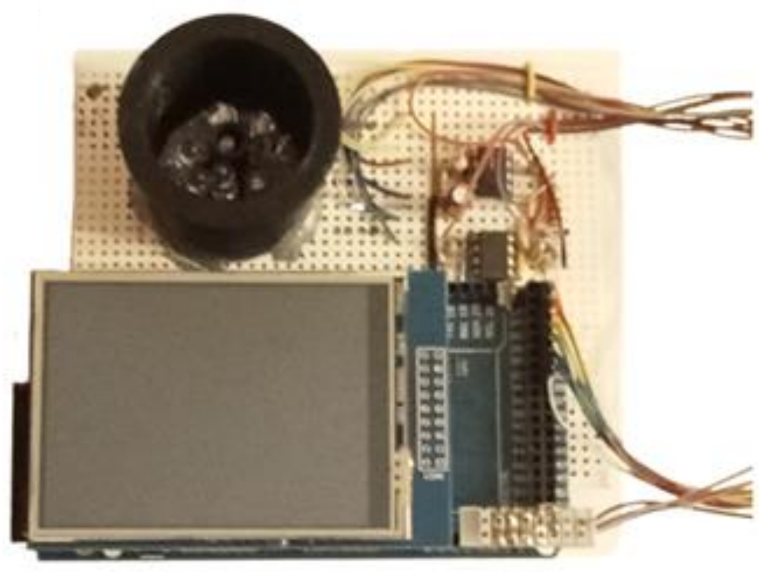
Email: franciscoj.fernandez05@estudiante.uam.es

MOTIVATION

The development and regulation of autotrophic living beings on our planet are controlled by **sunlight**. The most important sunlight-induced process is **photosynthesis**, which occurs due to some pigments, mainly **chlorophyll**, absorbing solar radiation within the visible electromagnetic spectrum range. a-Chlorophyll exhibits **strong absorption** in **blue** and **red** wavelengths, and **higher reflectance** in **green** and **near-infrared**. Therefore, by measuring the **reflectance spectrum** of the leaves, the superficial **concentration** of **a-Chlorophyll** can be estimated, and thus, information about the **physiological state** of the plant can be obtained. The result of spectral analysis is commonly summarized in the form of **vegetation indices**, which relate the reflectance in two or more wavelength intervals, or bands, such as the **NDVI**, which compares reflectance in the red and infrared bands. Nowadays, there are numerous commercial instruments that can determine some of the above indices. However, the **devices nowadays available** on the market have some **drawbacks**: (1) they are relatively **expensive** (more than USD 2000), which **limits** its access in **developing countries**; (2) most measure **only one or two vegetation indices**; and (3) the **geometry** of many of them does not allow to **perform measurements** on **non-leaf objects**, which limits their applicability. In this work, **a cost-effective instrument**, based on the **Arduino** open-source platform was **designed** and **implemented**, **solving the drawbacks** previously mentioned [1].

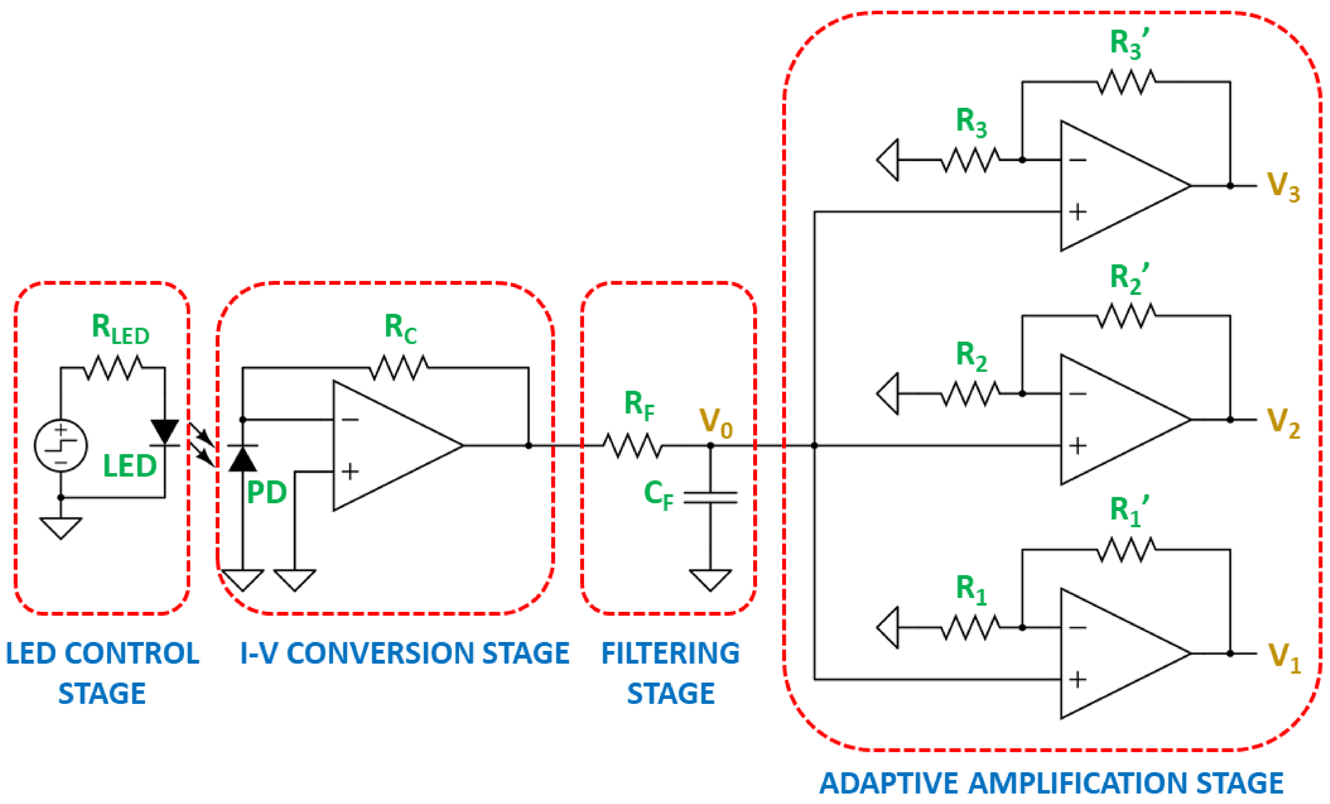
OPTICAL DESIGN





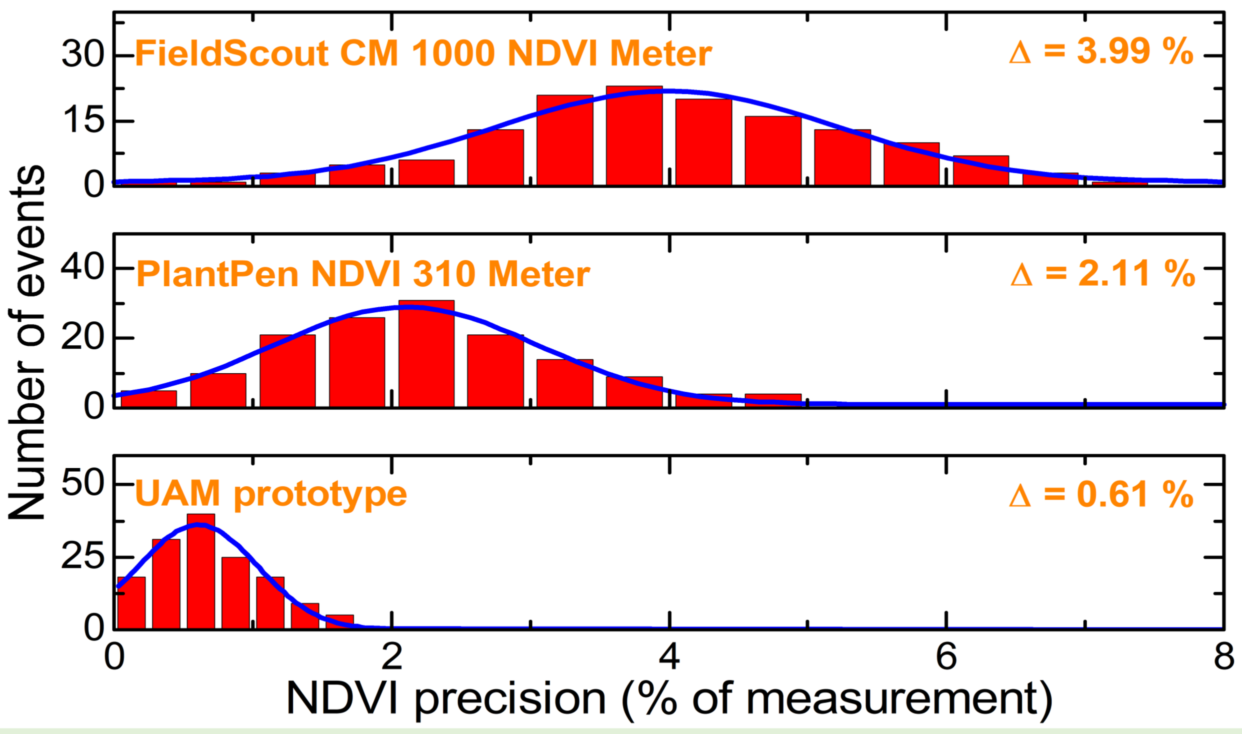
Measurements are performed on **7 bands**, from **blue** to **near - infrared**, and up to 9 vegetation indexed are computed. **Bill of materials < USD 65**.

SIGNAL ADQUISITION



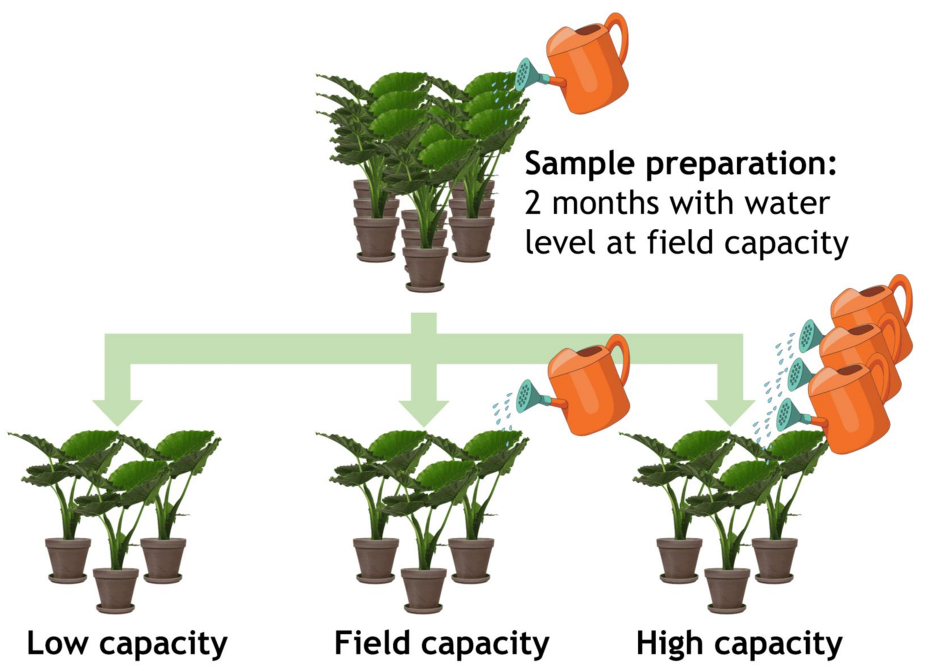
3 processing stages: (1) Low-pass filtering (to remove high frequency noise); (2) Adaptive amplification stage (to optimize the resolution of the microprocessor ADC); and (3) Digital synchronous filter (to remove low frequency noise)

NDVI PRECISION



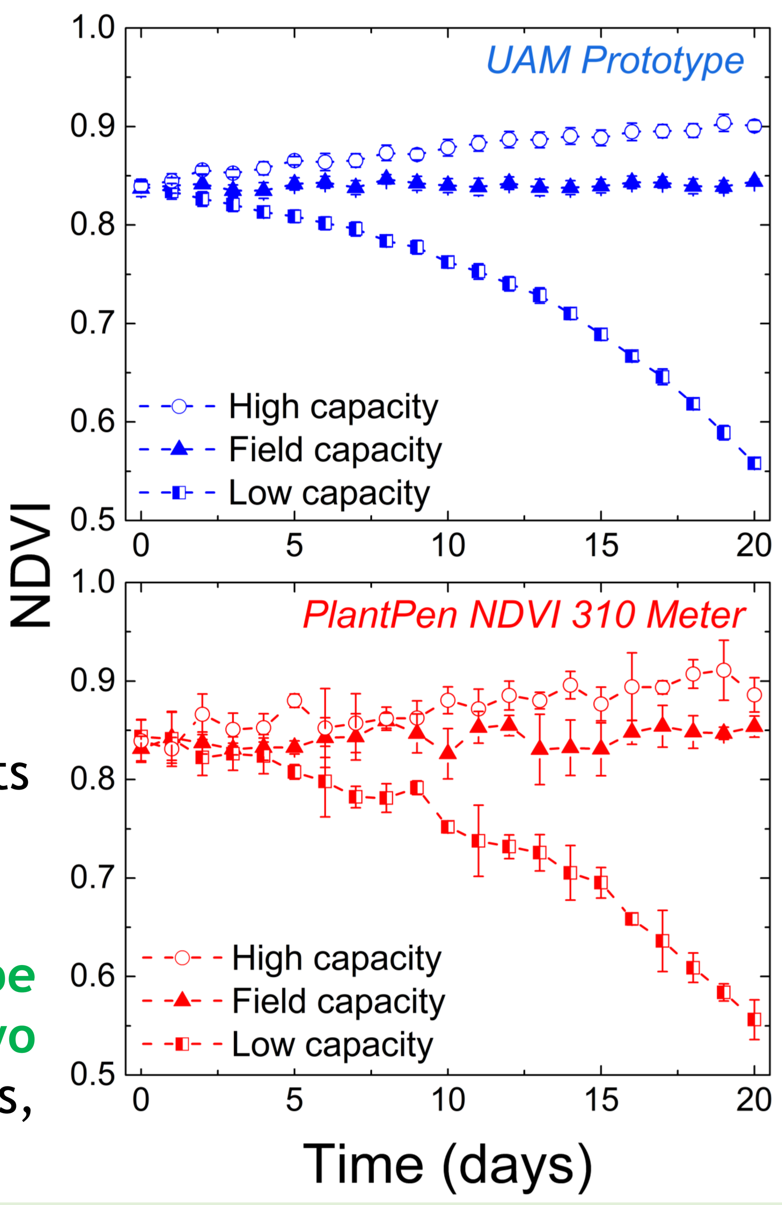
UAM prototype presents an **uncertainty three to six times lower** than available comercial instruments.

FIELD TEST: SENSITIVITY TO WATERING LEVEL



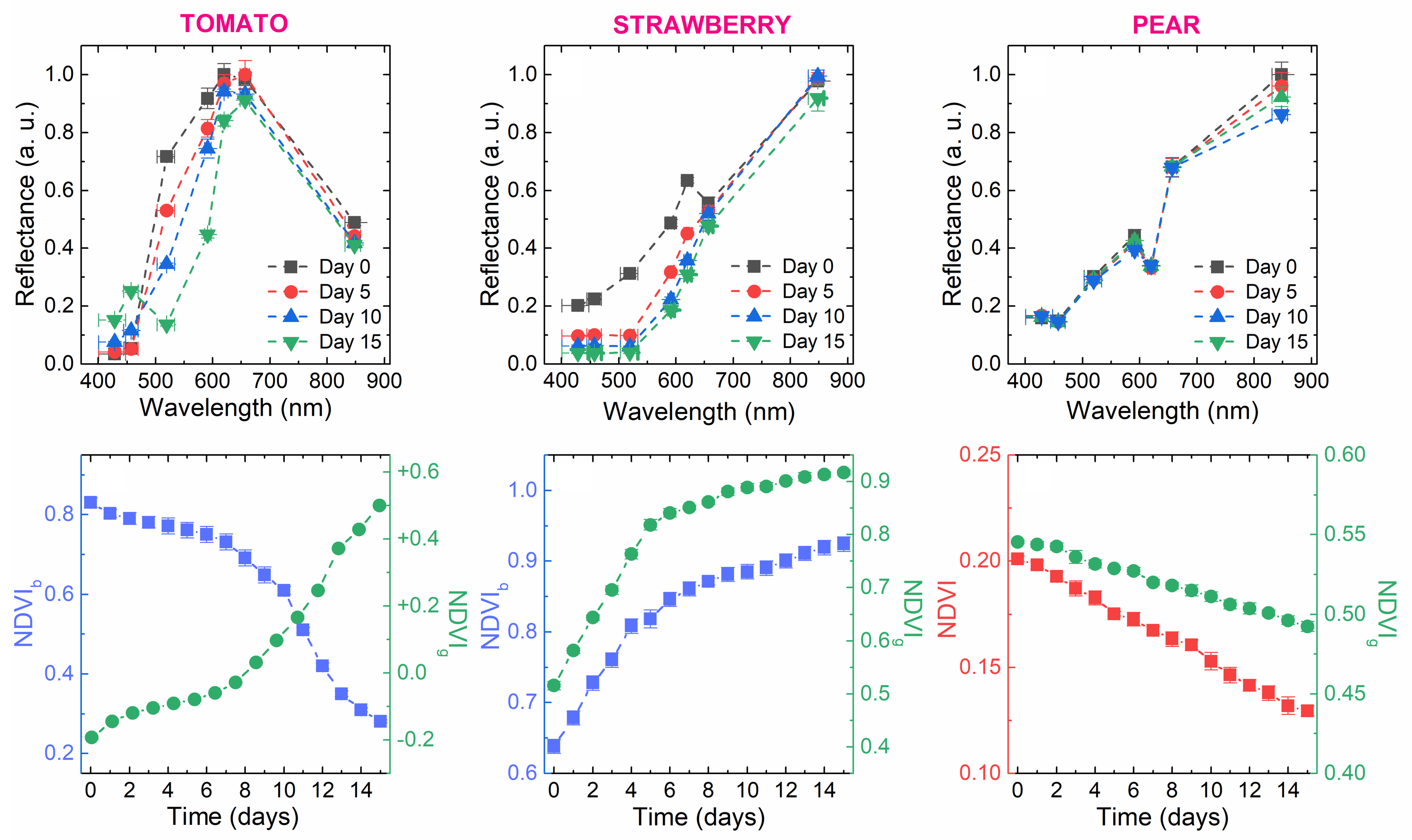
Experiment:
NDVI was measured for each set of plants daily, for 20 days.

Results:
Due to its lower uncertainty, **our prototype** allows **changes** to be observed **one or two days** after the change in irrigation conditions, much earlier than the commercial device.

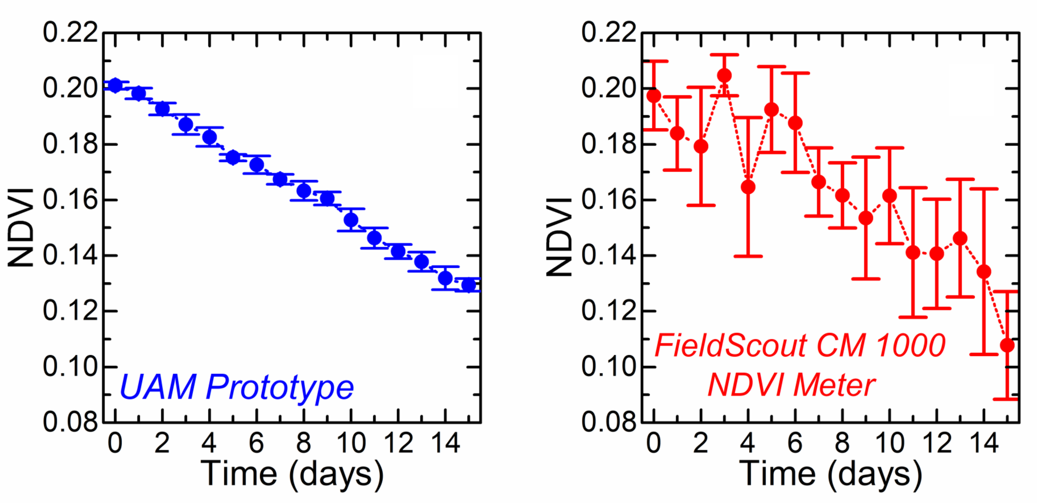


FIELD TEST: MONITORING FRUIT RIPENING

Experiment: Five pieces of round tomatoes (*Solanum lycopersicum*), strawberries (*Fragaria vesca*), and conference pears (*Pyrus communis*) were taken. Samples were preserved at 5 °C during the experiment. Reflectance measurements were performed daily for 15 days.



As for **tomatoes** and **strawberries** there is no significant change in the red and infrared bands, the **NDVI cannot be used** to monitor their ripening: **Instruments** that **only measure** the **NDVI** are **not applicable.**



For pears, the NDVI is applicable. With **our prototype** it is possible to observe **changes from one day to the next**, while with the **commercial**, the uncertainty is approximately **one week**, when the changes are already noticeable to the naked eye.

CONCLUSIONS

- A **spectrophotometer** based on the **open-source Arduino** platform was implemented, covering seven bands from blue to infrared and able to determine up to nine vegetation indices.
- The NDVI **uncertainty** value is **0.61 %**, between **three** and **six times lower** than that of commercial devices.
- The applicability of the prototype in **two field tests** has been tested, observing a **better result** than with the commercial devices.
- The **high precision** and **low-cost** of the prototype favors the access of this technology for farmers in **developing countries**, contributing to the fulfillment of **SDG 2 (Zero Hunger)** and **12 (Responsible Consumption and Production).**

REFERENCES

[1] F.J. Fernández-Alonso *et al*. Agriculture **13** 1467 (2023).

Universidad Autónoma de Madrid