



PERFORMANCE ASSESSMENT OF THE VL53L0X TIME-OF-FLIGHT SENSOR FOR AUTOMATED WATER LEVEL MONITORING IN CLASS A EVAPORATION PAN

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Abstract

The Class A Pan is widely used for estimating reference evapotranspiration (ET_o), a key parameter in irrigation management. Traditionally, water level readings are taken using a micrometric screw, which requires daily manual collection and is prone to operational errors. This study proposes an automated approach using the VL53L0X sensor, integrated with an Arduino Uno platform, aiming to evaluate its feasibility as an alternative to the conventional method. The sensor operates with Time-of-Flight (ToF) technology, emitting an infrared beam that reflects off an object and returns to the receiver, allowing precise distance measurement. To simulate the tank's stilling well, a 500 mL graduated cylinder was used with a floating white Styrofoam disc as the reflective surface. The initial point was set at 60 mm, and tests were conducted up to 70 mm, with 100 readings per level across four repetitions, totaling 4,400 measurements. Data were stored in Excel spreadsheets and statistically analyzed using arithmetic mean and standard deviation. Results indicated good sensitivity and repeatability of the sensor for millimetric variations. Automation enables integration with Internet of Things (IoT) systems, allowing remote data transmission, which is a significant advantage for producers with large cultivated areas. It is concluded that the VL53L0X shows potential to replace the micrometric screw, provided it is validated under real field conditions.

Keywords: Class A Evaporation Pan, Evapotranspiration, Agricultural Automation, Arduino, VL53L0X Sensor

INTRODUCTION

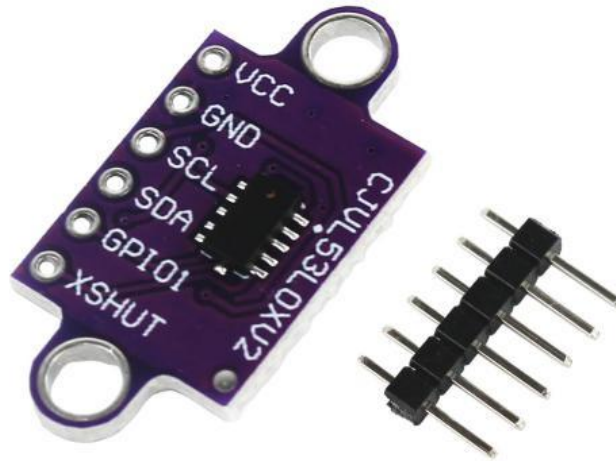
The Class A Evaporation Pan is a well-established instrument for estimating reference evapotranspiration (ET_o), a fundamental parameter for efficient irrigation management (Fernandes et al., 2004). ET_o represents the water demand of a reference crop under specific atmospheric conditions and is used to determine irrigation depths and manage water supply in agricultural systems (Conceição, 2025). Measurement of ET_o using the Class A pan is based on water level variation, traditionally assessed with a micrometric screw, which has a minimum resolution of 1 mm — equivalent to 1 liter of evaporated water per square meter.

Despite the high precision of the micrometric screw, its use requires daily manual readings at fixed times, making it susceptible to operational errors such as inaccurate readings, timing inconsistencies, and handling variability. These accumulated errors can compromise the accuracy of ET_o estimates, potentially leading to water excess or deficit, with negative impacts on plant physiological development and water use efficiency (Schwingel et al., 2001).

Given these limitations, this study proposes evaluating the technical feasibility of the VL53L0X sensor, illustrated in Figure 1, as an alternative to the manual reading system. This is a low-cost commercial optical sensor based on Time-of-Flight (ToF) technology, capable of performing distance measurements with high

resolution and stability (Stmicroelectronics, 2024). Integrating the VL53L0X into the Class A pan monitoring system would enable automated data collection, eliminating the need for operator travel and significantly reducing human error. With proper calibration, the sensor is expected to provide reliable measurements of water level variation, contributing to the modernization of irrigation management and the adoption of more precise and sustainable agricultural practices.

Figure 1. VL53L0X Sensor.



Source: Usinainfo, 2025.

MATERIALS AND METHODS

The study was conducted on a laboratory bench with the aim of simulating the operation of the stilling well of the Class A evaporation pan. For the simulation, a 500 mL graduated cylinder was used, vertically secured with a laboratory clamp to ensure proper leveling. On the outer surface, a millimeter-scale measuring tape was applied to allow precise verification of the water level, which was initially adjusted to the 60 mm mark, as shown in Figure 2.

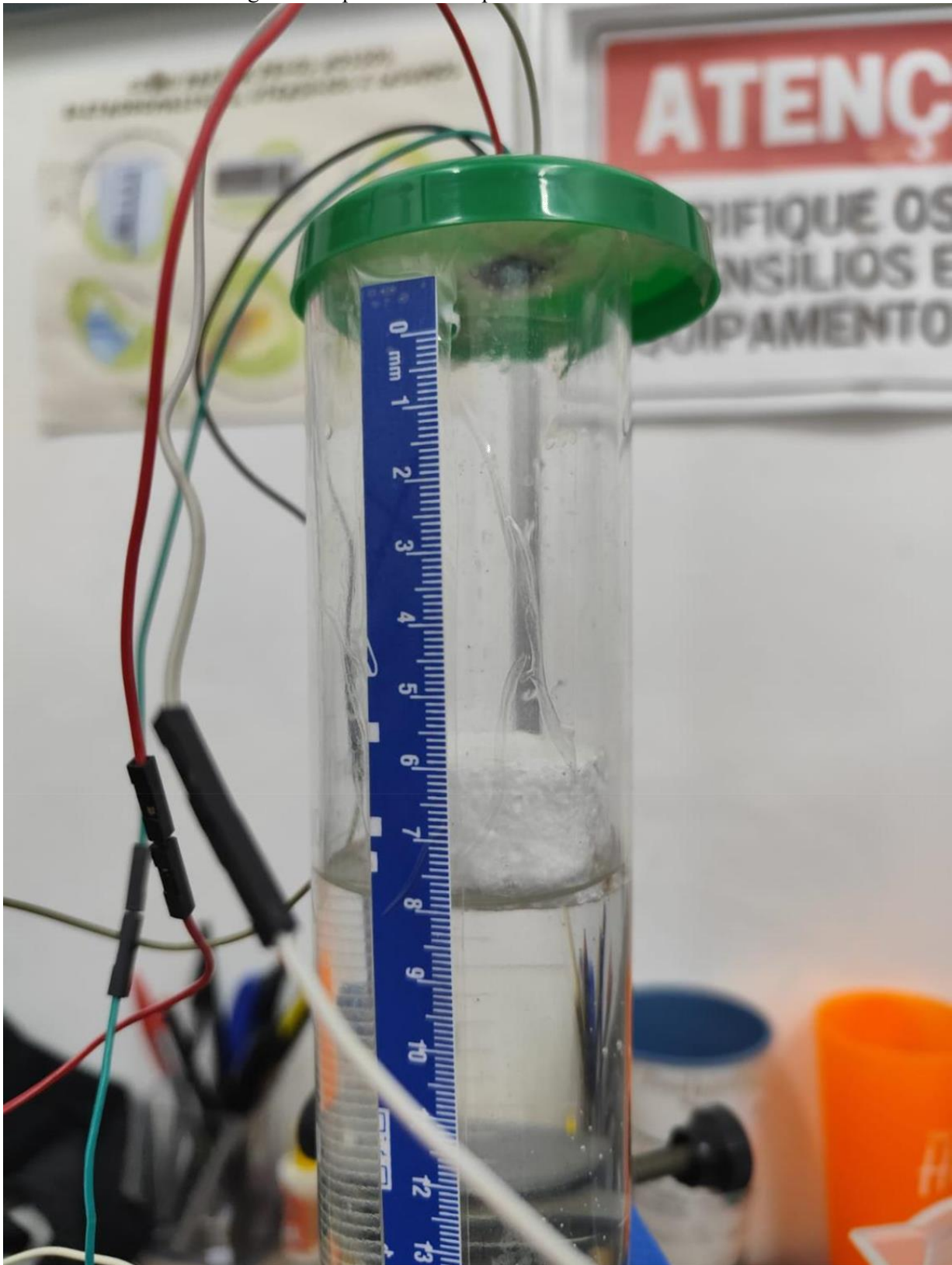
Evapotranspiration simulation was performed through controlled water withdrawal using a syringe connected to a silicone hose inserted into the graduated cylinder. After each withdrawal, the volume was transferred to a second 15 mL Falcon tube, allowing precise quantification of the extracted water. This procedure was repeated in all cycles to maintain a consistent withdrawal pattern and assess the sensitivity of the proposed system.

For automated water level data collection, the VL53L0X sensor was used—a low-cost optical device operating with Time-of-Flight (ToF) technology. The infrared sensor emits a light beam that, upon reaching the surface of an object, is reflected back to the receiver, enabling accurate distance measurement.

To ensure proper reflectivity for infrared detection, a floating white Styrofoam disc was placed on the water surface, serving as a reference plane and defined as the initial point (0 mm). This adaptation was necessary because water has low reflectance in the infrared spectrum and tends to absorb rather than reflect infrared radiation. Consequently, direct readings from the water surface are unreliable. The white Styrofoam disc, with its high reflectivity and thermal stability, provides a consistent and detectable surface for the VL53L0X sensor, enabling accurate distance measurements.

Tests were conducted up to 70 mm, totaling 11 levels. The VL53L0X was connected to an Arduino Uno, which executed a programmed algorithm to perform 100 readings per level upon receiving an initial command. For each new level — corresponding to a 1 mm water withdrawal — the cycle was repeated, following the logic diagram shown in Figure 3. The experiment was conducted four times to verify repeatability and stability.

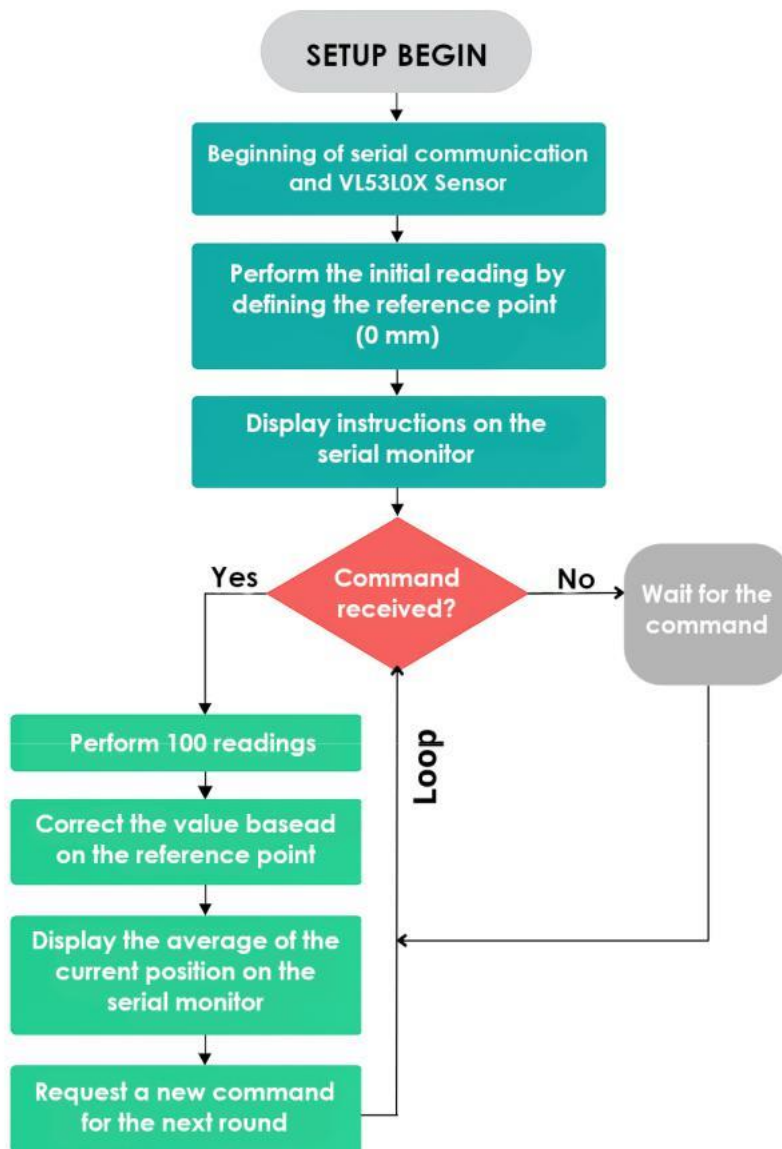
Figure 2. Experimental setup of the VL53L0X Sensor.



Source: Authors, 2025.

At the end of each experiment, the data were stored in Excel and statistically analyzed using arithmetic mean and standard deviation, aiming to assess the feasibility of the sensor as a replacement for the micrometric screw.

Figure 3. Programming logic diagram for the VL53L0X sensor.



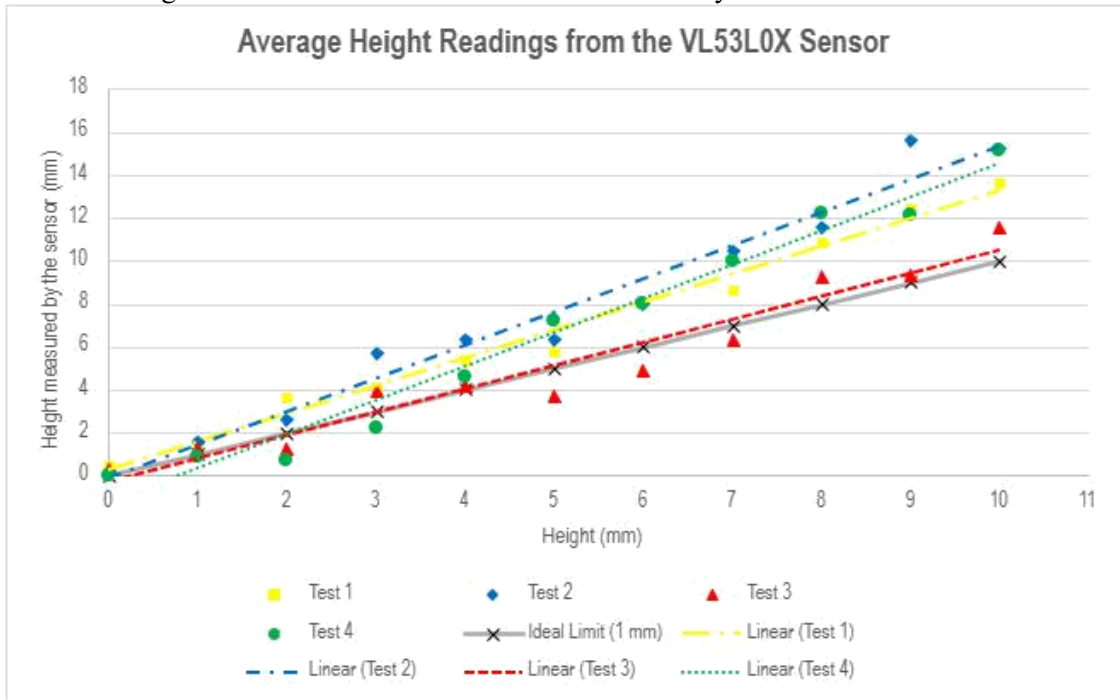
Source: Authors, 2025.

RESULTS AND DISCUSSION

The tests conducted with the VL53L0X sensor demonstrated satisfactory performance in detecting millimetric variations in water level under bench-simulated conditions. Over the course of four trials, a total of 4,400 readings were collected (100 per level, from 0 mm to 10 mm), enabling a robust statistical analysis of the sensor's response to gradual height changes.

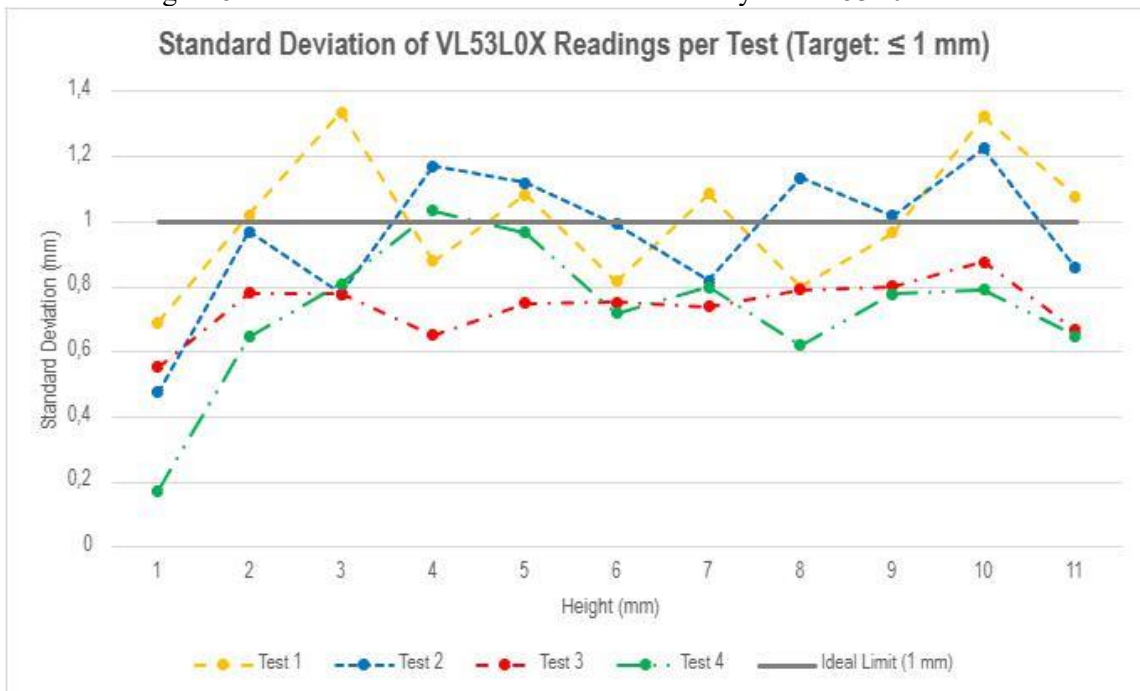
The arithmetic mean of the readings per level — illustrated in Figure 4 — showed consistent behavior, with a linear increasing trend corresponding to water withdrawal. In 82.5% of the cases, the sensor was able to distinguish 1 mm variations between levels, highlighting its sensitivity for high-resolution applications. The standard deviation of the measurements, as shown in Figure 5, remained ≤ 1 mm in 77.5% of the analyzed points, indicating good stability and repeatability, even under controlled bench conditions.

Figure 4. Arithmetic mean of the data collected by the VL53L0X sensor.



Source: Developed by the authors, 2025.

Figure 5. Standard deviation of the data collected by the VL53L0X sensor.



Source: Developed by the authors, 2025.

The use of a white Styrofoam disc as a reflective surface proved effective in ensuring the capture of the infrared beam, avoiding optical interference. The 3-second interval between readings, defined based on the manufacturer's specifications, was adequate for signal stabilization and noise reduction. Automated data collection, performed through an embedded algorithm on the Arduino Uno platform, demonstrated operational feasibility by eliminating the need for manual measurements and reducing potential human errors.

Furthermore, integrating the sensor with Arduino opens possibilities for implementing Internet of Things (IoT)-based systems, allowing the collected data to be transmitted in real time to digital platforms. This functionality represents a significant advancement over the traditional micrometric screw method, which requires physical travel to the pan for data collection. In agricultural properties with large territorial extensions,

such as areas exceeding hundreds of hectares, this automation can reduce operational costs, optimize labor time, and enhance water management efficiency.

Although a direct comparison with the traditional micrometric screw reading method was not conducted, the results obtained in this bench simulation suggest that the VL53L0X sensor has potential for applications in Class A evaporation pans. The observed precision, combined with the possibility of automation and reduction of human error, supports the continuation of the study under real field conditions to validate its replacement in irrigation management systems.

Therefore, the data obtained reinforce the technical feasibility of the VL53L0X as a low-cost, high-precision alternative for automating water level readings in Class A pans, contributing to improved water management in irrigated agriculture.

FINAL CONSIDERATIONS

The results obtained from the bench simulation indicate that the VL53L0X sensor shows promising performance for applications in Class A evaporation pans, with the ability to detect millimetric variations in water level in a stable and repeatable manner. The use of a white Styrofoam disc as a reflective surface and the standardization of the reading interval contributed to the reliability of the data. Automated data collection, performed through an embedded algorithm on the Arduino Uno platform, demonstrated operational feasibility by eliminating the need for manual measurements and reducing potential human errors.

Although a direct comparison with the traditional micrometric screw method was not conducted, the data suggest that the sensor may be a viable alternative, provided it is properly calibrated and validated under real field conditions. Statistical analysis using arithmetic mean and standard deviation reinforces the consistency of the measurements, pointing to a low-cost, accessible system with automation potential. Thus, this study represents an initial step toward technological solutions for more efficient water management, paving the way for future validations and applications in agricultural environments.

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