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Design and test of a low-cost weather station for monitoring green roofs

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Highlights

- Green roofs' meteorological and hydrological monitoring is necessary.
- This abstract presents the design and test of a low-cost weather station on the green roof.
- Low-cost sensors show satisfactory results compared with conventional ones.

Introduction

Green roofs have been proven to encompass many benefits for rainwater management and urban environment (Berardi et al., 2014). Knowledge of on-site meteorological quantities, including rainfall (Nawaz et al., 2015) as well as the estimation of local potential evapotranspiration, coupled with measurements of storage capacity and outflow, can help optimize their operation (flow regulation, stored volume and watering management). But the costs of conventional meteorological instruments limit their generalization to green roofs. Technological advances in metrology have led to the miniaturization of systems, the reduction in costs, and the development of open-source programming (Delaine et al., 2019). These advances offer new perspectives for stormwater management facilities real-time monitoring. This work aims to adapt a low-cost weather station to the specific context of green roofs monitoring, measuring the following parameters: air temperature, humidity and pressure, wind direction and speed, rainfall intensity and solar radiation. The data obtained are compared with those provided by a conventional weather station whose performance is known.

Methodology

Site

The experimental site is the green roof test bench GROOF installed on the roof of a building on the INSA Lyon campus in Villeurbanne. A traditional weather station is also installed on the same site as reference. Figure 1 shows the reference traditional weather station (left) and the low-cost weather station (right) with one of the platforms in the background which will be equipped with a green roof.



Figure 1. Reference traditional weather station on the left (from left to right and top to bottom): anemoscope, anemometer, pyranometer and air temperature and humidity sensor. Low-cost weather station on the right (from left to right and top to bottom): anemoscope, anemometer, rain gauge (at the back), pyranometer, and air temperature, humidity, and pressure sensor.

Sensors

Table 1 indicates the reference traditional sensors and the low-cost sensors used for each measurement parameter and their respective prices.

Table 1. Traditional and low-cost sensors installed on the GROOF experimental platform.

Measured parameter	Traditional sensors	Price range	Low-cost sensors	Price range
Rainfall intensity	OTTPluvio ² L	~ 4250 €	WH-SP-RG	~ 15 €
Wind direction and speed	Campbell Scientific 03002	~ 750 €	WH-SP-WS01, WH-SP-WD	~ 15-20 €
Air temperature and humidity	Campbell Scientific CS215	~ 280 €	BME280	< 5 €
Air pressure	No	No	BME280	< 5 €
Solar radiation	Campbell Scientific CS300	~ 300 €	JXBS-3001-ZFS	~ 100 €

Data acquisition

All the low-cost sensors are connected to an Arduino Nano microcontroller (Arduino, New York, NY, USA). The Arduino is connected to a computer which acquires and stores data every minute.

Calibration of the rain gauge

A dynamic calibration of the WH-SP-RG rain gauge was performed over the range of 20 to 140 mm/h. The response of the sensor is linear: $I_m = b \cdot I_t$ with I_m and I_t the measured and calibrated intensities respectively (mm/h) and b the slope of the calibration line: $b = 0.9764$ with a standard uncertainty $u(b) = 0.0039$.

Results and discussion

The low-cost weather station was installed in mid-March 2021. As an example, the results of temperature, humidity, solar radiation and wind speed sensors, compared with traditional sensors data from April 16 to April 29, 2021 are shown in Figure 2, and Figure 3 shows the wind direction sensors data.

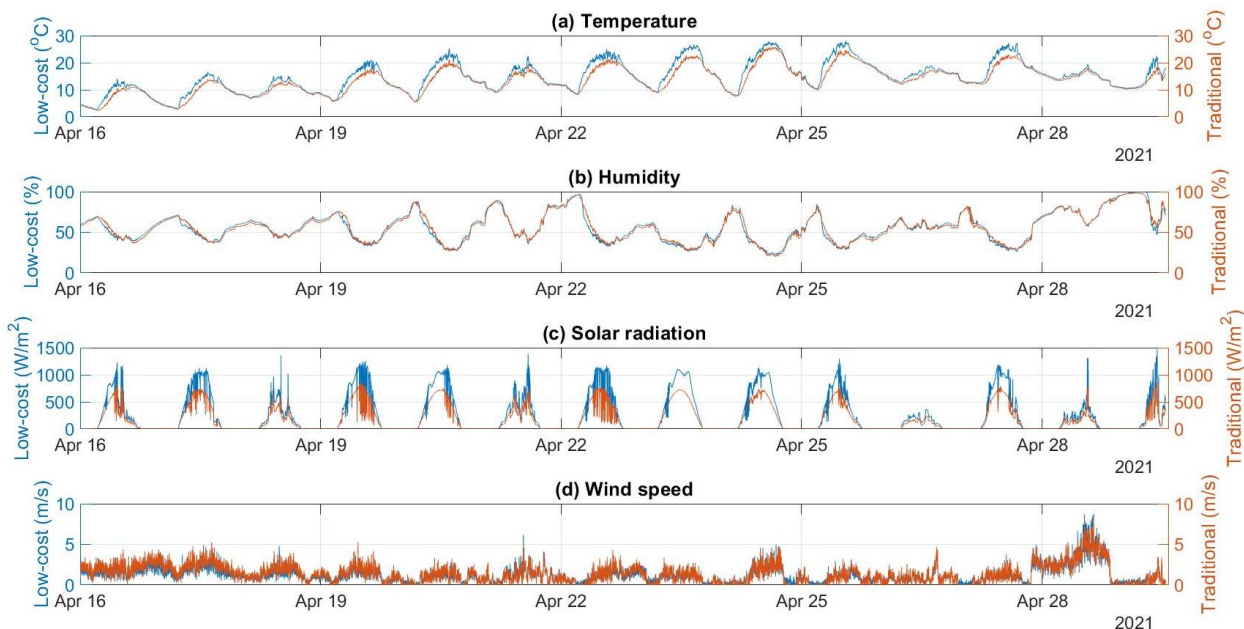


Figure 2. Low-cost weather station data (blue) from April 16 to 29, 2021, compared with data from traditional weather station (orange), including temperature, humidity, solar radiation, and wind speed.

Globally, the data provided by the low-cost sensors are consistent with the data provided by traditional sensors. A more detailed analysis shows the BME280 temperature sensor has higher value than the traditional one due to its self-heating. This slight difference may also involve other factors. The low-cost pyranometer provides higher values than the traditional one. But, in fact, the true value is in the middle

according to a reference thermopile pyranometer nearby. Figure 3 presents the comparison of the two anemoscopes: results are similar, and differences could be explained by local variations of the wind.

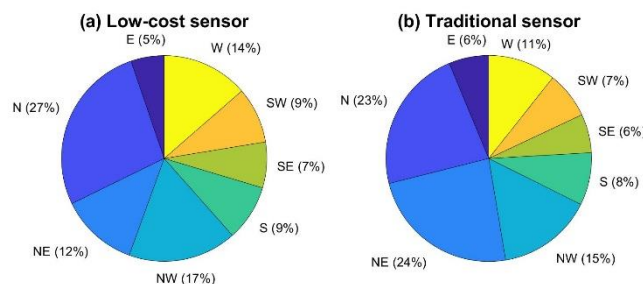


Figure 3. Wind direction data obtained from low-cost weather station (left) from April 16 to 29, 2021, compared with wind direction data provided by traditional weather station (right).

We have also obtained data from the low-cost WH-SP-RG rain gauge and BME280 pressure sensor. Since the equivalent traditional sensors are not operated yet, it is impossible to compare these initial data. But the sensors work well without failures.

Conclusions and future work

After three months of field testing, the low-cost weather station has been operating stably and is globally satisfactory, this needs to be confirmed on the long-term. There are some lessons learned. The specifications of low-cost and traditional sensors are not always the same: the comparison of values requires a certain amount of data pre-processing. Before use, low-cost sensors should be calibrated, and the information provided by the manufacturer should be carefully checked. Therefore, it is essential to systematically check and control everything (measurement principle, conversion and correction functions, etc.).

In order to enrich the comparison and better evaluate the reliability of low-cost sensors, a second low-cost weather station is being installed next to the first one, equipped with an optical rain gauge and a pyranometer using light sensors. The evaluation and certification of low-cost weather stations will be conducted during at least one complete hydrological year with comparison with data from conventional weather stations. These data will make it possible to characterize the local climatic conditions applied to the green roofs of the GROOF experimental platform and determine the local potential evapotranspiration.

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