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Comparative analysis of daily climatic data from a conventional Weather station and an automatic Weather station at the La Mé station in Côte d'Ivoire

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Abstract

Accurate weather monitoring systems are essential in developing countries. Indeed, they are necessary for small-scale research such as precision agriculture. However, the use of non-standardized measuring instruments raises concerns about the quality of the data collected. Alongside traditional measuring instruments, the use of automatic weather stations is becoming increasingly common. However, it is necessary to ensure the consistency of the data collected by these measuring devices. The study conducted at the La Mé station allowed for a comparison of data from two weather stations (a traditional manual station and an automatic station) over 32 days, from mid-June to mid-July. The method used to obtain data varies from one station to another. At the conventional weather station, readings are taken once, twice, or three times a day, depending on the parameter. At the automatic weather station, sensors continuously record meteorological data every hour. The results show strong positive correlations (0.998 for precipitation and 0.938 for radiation) between the two stations, indicating a similar trend in the values of the parameters studied. However, significant differences were found between the stations for average temperature, radiation, and relative humidity. This study shows that the data collected by the two stations are consistent and are necessary to ensure complementary measurements, thereby enabling better agroclimatic monitoring of oil palm cultivation in La Mé.

Keywords: Compare; Weather station; Conventional; Automatic; La Mé

1. Introduction

Agriculture occupies a strategic place in the economy and social development of Côte d'Ivoire. It constitutes one of the pillars of economic growth, job creation, and food security. However, it faces numerous constraints such as soil poverty, pest and disease attacks, and especially climate change.

These constraints are driving researchers to redouble their efforts to find solutions. In the context of climate change, considering climate is becoming increasingly important in agronomic research. Moreover, decisions in the agricultural sector are often based on weather conditions (Dabrowski et al., 2023). Thus, weather monitoring plays a central role in understanding the hydrological cycle, weather forecasting, risk assessment and management, as well as agricultural planning (Dombrowski et al., 2021). Since then, agricultural stakeholders have been conducting weather monitoring to establish a planting schedule.

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In oil palm-growing regions, the study of local climate is essential for the planning and sustainable management of agricultural crops (Kouamé et al., 2019; MINADER, 2021). At La Mé, a CNRA experimental station dedicated to oil palm cultivation, regular monitoring of meteorological parameters such as temperature, humidity, precipitation, and solar radiation allows for the assessment of environmental conditions influencing the growth and production of plantations. Traditionally, these observations were conducted using conventional weather stations, which relied on manual instruments requiring daily readings by an observer. The advent of automatic weather stations, incorporating digital sensors and real-time recording systems, has profoundly transformed the collection and analysis of climate data. In climatology, the transition from conventional manual weather stations (MWS) to automatic weather stations (AWS) poses challenges for maintaining the homogeneity of long-term data series (Lukasov et al., 2024).

In this context, a key question arises: to what extent do conventional and automatic weather stations provide comparable and reliable data for agroclimatic monitoring of oil palm cultivation at the CNRA station in La Mé?

Comparing these two types of weather stations in La Mé is therefore particularly important. It would make it possible to assess the reliability, accuracy, and timeliness of the data obtained, as well as their relevance for agricultural research and the technical management of plantations. This study aims to highlight the advantages and limitations of each weather station and the potential synergies between them for agroclimatic monitoring of oil palm cultivation.

2. Materials and methods

2.1. Study area

The study site (CNRA-La Mé research station) is located in the southeast of Côte d'Ivoire. It is bounded to the north by the village of Kongofon, to the south by the village of Aghien Télégraphe, and to the east by the village of Ahoutoué and the Mé River. The site is characterized by a hot and humid Attian-type climate; a topography consisting of a low plateau and lowlands; deep, lumpy ferralitic soil with fine particles; a sandy-clay subsoil belonging to the ferralsol group; and, most importantly, an acceptable annual water deficit. These characteristics are well suited to the long-term cultivation of oil palms. (Ballo, 2009). The vegetation at this site consists of forest, with a hydrographic network comprising the Mé River and the Aghien Lagoon (Figure 1).

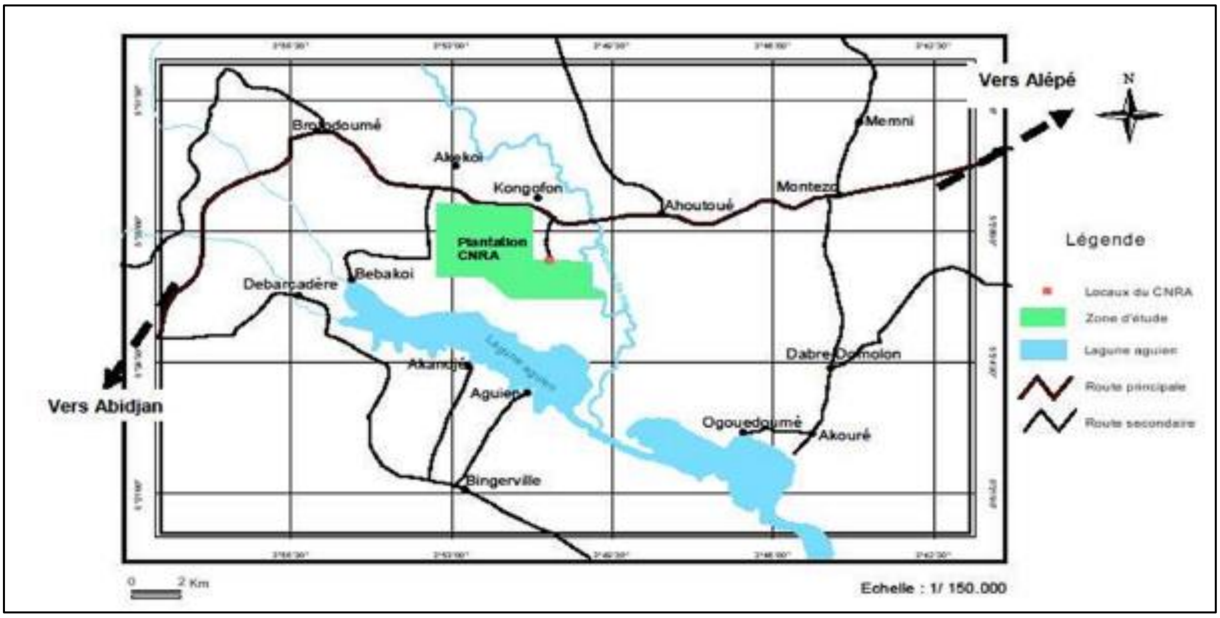

Figure 1 Geographical location of the La Mé station (Source: Ballo, 2009**)**

2.2. Plant material

The plant material consists of oil palms. A plant has a high water requirement. Oil palms require climatic conditions that are as consistent as possible throughout the year. According to Turner and Gilbank (1974), these conditions are found in the intertropical zone and are characterized by:

- Annual rainfall of 1,800 to 2,000 mm, distributed evenly throughout the year, meaning that monthly rainfall requirements range from 120 to 150 mm;
- A minimum temperature of 18 °c and a maximum temperature of 33 °c;
- A monthly average relative humidity of over 75% at 30 °c;
- At least 5 hours of sunshine per day.

2.3. Technical Equipment

2.3.1. Conventional weather station

The conventional weather station (MWS) at La Mé consists of a set of instruments designed to manually measure and record various meteorological parameters. It is typically located on an open, flat, grassy, and well-ventilated site, approximately 100 meters away from obstacles (such as trees and buildings) likely to alter the climatic conditions.

The instruments are arranged in a standard meteorological station, in accordance with the recommendations of the World Meteorological Organization (WMO).

This station comprises seven instruments capable of measuring seven parameters. In this study, only four instruments a rain gauge, a pair of thermometers (Max and Min), a pyranometer, and a psychrometer were considered (Figure 2).

A: Rain gauge, B: Thermometers, C: Pyranometer, D: Psychrometer

Figure 2 Equipment for measuring meteorological parameters at the traditional La Mé station

2.3.2. Automatic weather station

An automatic weather station (AWS) is a modern device that automatically, continuously, and digitally records data on various meteorological parameters using electronic sensors connected to a data acquisition and transmission system (Figure 3). It operates using an automatic data logger powered by a solar panel. It is also equipped with a remote transmission system (GSM, GPRS, or satellite) that allows data to be transferred to a central server.

This weather station is typically installed under the same environmental conditions as a conventional weather station: on flat, open ground covered with short grass, and approximately 100 meters away from any obstacles.

This station consists of weather sensors, which are devices that measure climatic variables. Like a conventional weather station, four parameters are measured. These are:

- An air temperature sensor;
- a relative humidity sensor;
- an automatic rain gauge;
- a solar radiation sensor (pyranometer).

1: solar panel, 2: temperature and humidity sensor, 3: 4: rain gauge, 5: antenna, 6: data logger

Figure 3 Components of the automatic weather station at La Mé

2.4. Collecte de données météorologique

The weather observations for this study were collected over 32 consecutive days between June and July 2025. At all stations, the meteorological parameters measured were precipitation, temperature, solar radiation, and humidity.

2.4.1. Conventional weather station

Data collection was conducted in accordance with the standards of the Agency for Air Navigation Safety in Africa (ASECNA) and the Society for Airport, Aeronautical, and Meteorological Operations and Development (SODEXAM).

Weather readings for precipitation and humidity were taken three times a day, at 7:00 GMT, 12:00 GMT, and 17:00 GMT. Precipitation was measured using a manual rain gauge installed outdoors, while humidity measurements were taken using a psychrometer to determine the relative humidity of the air.

With regard to air temperature, weather data were collected daily at 7:00 a.m. GMT and 5:00 p.m. GMT using a pair of thermometers, one to measure minimum temperatures (Mini) and the other to measure maximum temperatures (Maxi).

The pyranometer, meanwhile, was used to measure daily total solar radiation; it indicates the amount of solar energy available for photosynthesis. Data collection was performed daily at 7:00 a.m. GMT.

2.4.2. Automatic weather station

The meteorological parameters measured at the automatic station were similar to those at the conventional station. The station's automatic sensors continuously record meteorological data every hour.

An automatic rain gauge, a temperature sensor, a relative humidity sensor, and a solar radiation sensor, respectively recorded data on rainfall, air temperature, real-time relative humidity, and solar radiation.

2.5. Management of Daily Weather Data

2.5.1. Conventional station

With the exception of solar radiation, for which data were collected once a day, the manual data recorded in the daily observation logs were used in calculations.

The daily average temperatures, expressed in degrees Celsius (°C), were calculated using the following formula:

$$T_{Moy} = \frac{T_{Max} + T_{Min}}{2}$$

Where, TMoy = daily average temperature; TMax = maximum temperature; TMin = minimum temperature

Note: The maximum temperatures were those recorded the previous day at 5:00 p.m. GMT.

Daily rainfall, expressed in millimeters (mm), was calculated by summing the values recorded consecutively at 12:00 p.m. GMT, 5:00 p.m. GMT, and 7:00 a.m. GMT the following day.

Regarding humidity, relative humidity is expressed as a percentage (%). To calculate this, each data point collected at 7:00 a.m. GMT, 12:00 p.m. GMT, and 5:00 p.m. GMT was converted to a percentage using psychrometric conversion tables. The average of these three values, expressed as a percentage, constituted the relative humidity data for that day.

2.5.2. Automatic weather station

The measurements were automatically saved to the station's internal memory (data logger), which stored the data for several days or weeks, depending on its storage capacity.

The data was automatically transferred to a central server via a GSM/GPRS modem. In the event of a network outage, the data logger retained the data until the connection was restored.

2.6. Data processing and analysis

Daily data, regardless of the meteorological parameter, were compared based on the type of weather station. First, Excel was used to create graphs, perform regressions, and calculate Pearson's correlation to assess the strength of the association between the variables from the two data sources. On the other hand, the collected data were processed using IBM SPSS Statistics 22 software. Normality tests were performed to conduct parametric statistical tests. Since normality was met, the variables studied were compared using a one-way analysis of variance. Comparisons of means were performed at the p=0.05 level using the Student-Newman-Keuls test. The various graphs and histograms were created using Excel.

3. Résult

3.1. Rainfall or Precipitation

Figure 4 shows a similarity between the two stations. However, rainfall amounts were slightly higher at the conventional weather station. There were 15 rainy days out of 32 days at both stations, and the total rainfall was 169.7 mm at the conventional weather station compared to 159.5 mm at the automatic weather station.

The t-test for paired samples did not reveal any significant differences between the two stations (p=0.208), with a mean difference of 0.316 mm. Furthermore, the standard deviation between the rainfall measurements of the two stations was 1.389, with a strong positive correlation of r = 0.998 (Table 1).

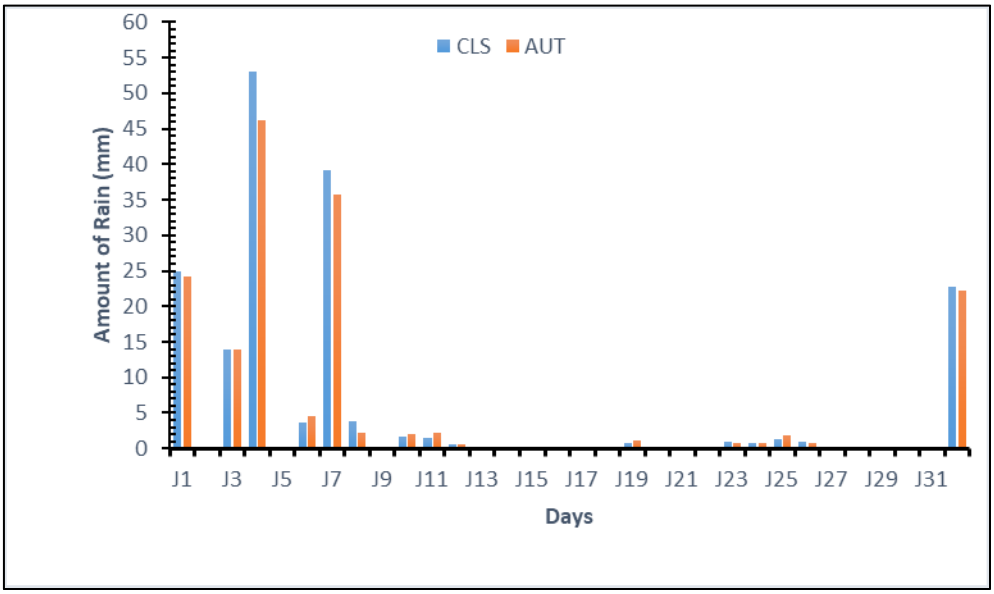

Figure 4 Precipitation at the two weather stations in the Mé

Table 1 T-test for paired samples comparing rainfall data from two stations

Comparison pair	Average Difference	Standard deviation	Correlation	Sig. (bilateral)
Pluv CLS - Pluv AUT	0.316	1.389	0.998	0.208

3.2. Average Temperature

The graph shows the trend in average temperatures recorded at the two stations. These temperatures follow a very similar trend over the study period; the curves are virtually superimposed. Temperatures generally range between 24°C and 29°C. (Figure 5).

The t-test for paired samples reveals a significant difference between the average temperatures recorded by the conventional and automatic stations (p = 0.002). The conventional station recorded significantly higher temperatures than the automatic station, with a mean difference of 0.56°C. However, the standard deviation between the two weather stations was 0.945, with a positive correlation (r = 0.626) (Table 2).

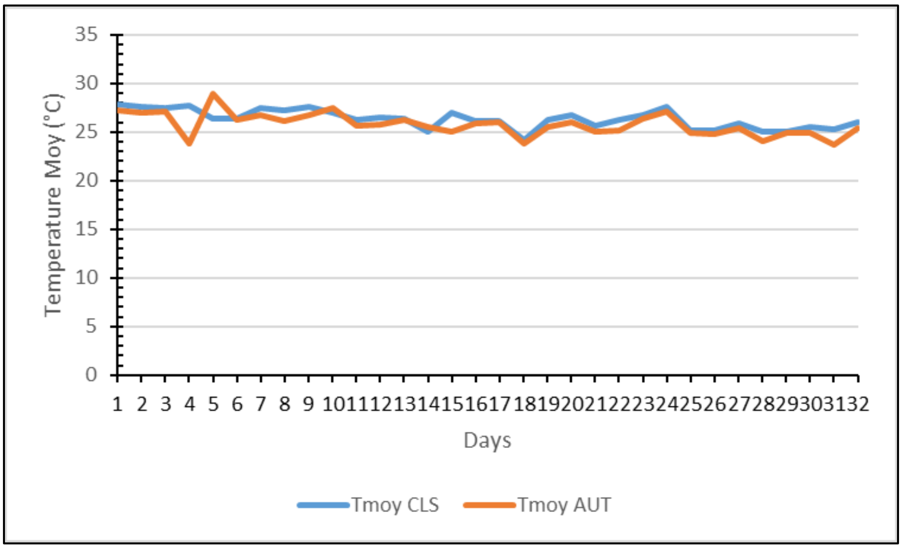

Figure 5 Comparative temperatures from the two weather stations in the Mé

Table 2 Paired t-test comparing the average temperatures of two stations

Comparison pair	Average Difference	Standard deviation	Correlation	Sig. (bilateral)
Tmoy CLS – Tmoy AUT	0.556	0.945	0.626	0.002

3.3. Radiation solaire

Figure 6 shows that the curves exhibit nearly identical trends. In fact, at both stations, the lowest solar radiation levels were recorded on Day 25. Regardless of the day, the solar radiation value provided by the conventional station was higher than that recorded by the automatic station.

The t-test for paired samples reveals a significant difference between the radiation levels recorded by the conventional and automatic stations ($p = 0.000$). The conventional station shows significantly higher radiation levels than the automatic station, with an average difference of 127.781 W/m^2. However, the strong positive correlation ($r = 0.938$) indicates a similar trend in radiation levels over the study period. The standard deviation between the two stations was 92.498 (Table 3).

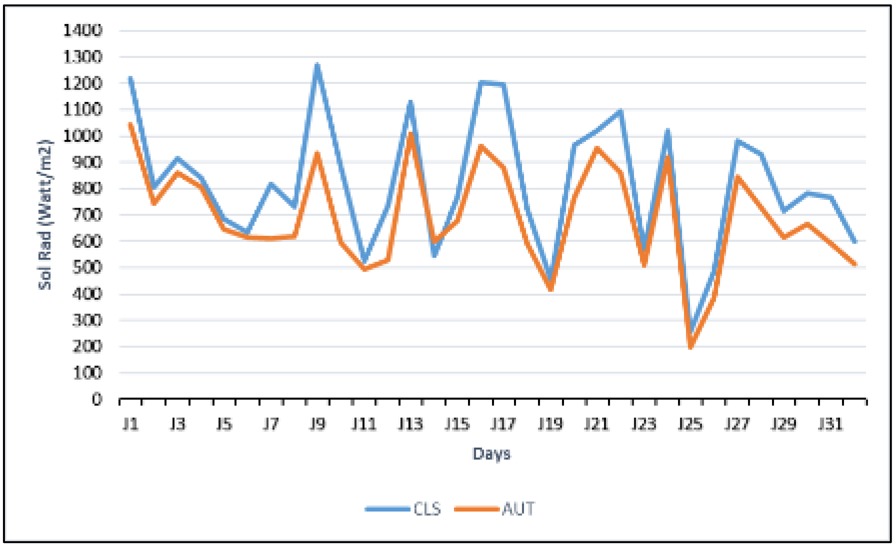

Figure 6 Evolution of solar radiation at the two weather stations in the Mé

Table 3 Paired t-test comparing radiation levels at the two stations

Comparison pair	Average Difference	Standard deviation	Correlation	Sig. (bilateral)
RD CLS – RD AUT	127,781	92,498	0.938	0.000

3.4. Relative Humidity

Figure 7 shows that relative humidity values range from 74% to 89% for the conventional station and from 80% to 95.91% for the automatic station. The curves exhibit nearly identical trends. On every day, the relative humidity value provided by the conventional station was lower than that recorded by the automatic station.

The t-test for paired samples reveals a significant difference between the relative humidity recorded by the two stations ($p = 0.000$), with a mean difference of -6.296%. However, the positive correlation ($r = 0.820$) indicates a similar trend in humidity over the study period. The standard deviation between the two stations was 2.373 (Table 4).

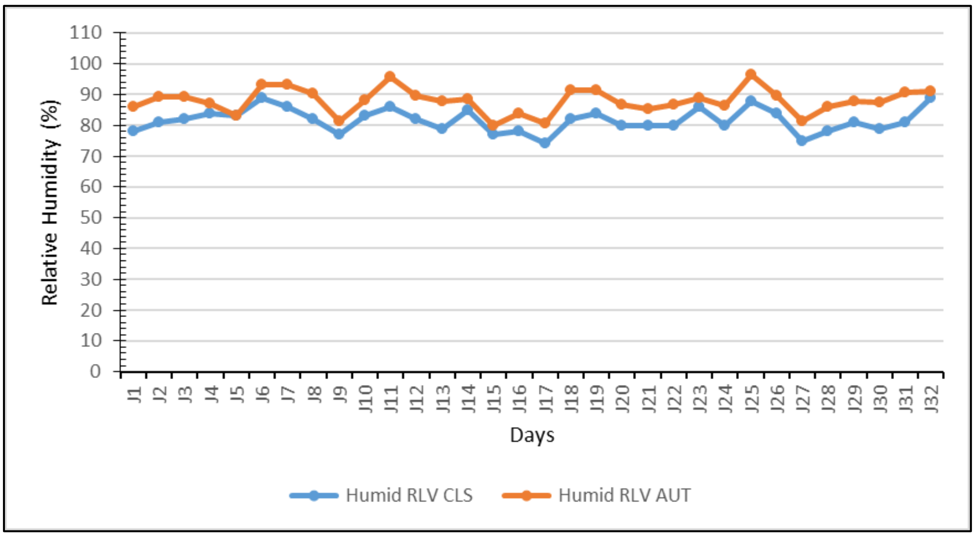

Figure 7 Changes in relative humidity at the two weather stations in the Mé

Table 4 Paired t-test comparing the relative humidity at the two stations

Comparison pair	Average Difference	Standard deviation	Correlation	Sig. (bilateral)
HR CLS – HR AUT	-6,296	2,373	0.820	0.000

3.5. Some advantages and disadvantages of the two stations

During the collection of meteorological data, some strengths and weaknesses of the two weather stations were listed in Table 5.

Table 5 Some advantages and disadvantages observed at both stations

	Advantages	Disadvantages
Conventional Station	Natural data, no costs involved; Not dependent on electricity, so no power outages; Data is always available.	Shortage of daily laborers; In the event of staff illness; In the event of heavy rain, observers are unable to collect data; Data is sometimes incomplete; Errors in recording values during data collection.

Automatic Station	Data collection without the need for on-site visits; No labor issues; Provides a digital signal (hourly); Continuous, real-time recording of climate parameters; Reduced human error; Automatic data transmission and archiving; Facilitates statistical analysis and climate modeling.	Requires a power supply in the event of a power outage; Involves operational costs such as connection fees and maintenance; Occasional outages that disrupt data flow or result in missing values; Lack of trained maintenance personnel; Technical failures; sensitive to calibration.

4. Discussion

The rainfall values (cumulative totals of 169.7 mm versus 159.5 mm) and the trends in the curves, as indicated by the strong positive correlation of r = 0.998, demonstrate a similarity between the two weather stations. Furthermore, the rainfall data from the two stations are significantly similar (p=0.208) with a standard deviation of 1.389, which attests to the low variability of daily values, resulting in homogeneous data. Consequently, this analysis indicates that the rainfall data recorded by the two stations are reliable and that there is complementarity between these two stations for agricultural monitoring. This result is consistent with that of Leroy, 2018. According to him, meteorological parameters, such as precipitation, measured at ground level can be compared to observations from automatic weather stations (AWS).

When comparing average temperatures, the conventional station recorded significantly higher temperatures (p = 0.002) than the automatic station. However, the standard deviation is 0.945, which is less than 1, with a positive correlation (r = 0.626). Muita et al., 2021 also noted strong associations between TAHMO (automatic station) data and manual stations for minimum (r = 0.65) and maximum (r = 0.86) temperatures. Although there is a significant difference, the standard deviation value indicates a convergence of the data recorded at the two weather stations. While air temperature is one of the most difficult environmental parameters to measure accurately, and according to Dombrowski et al., 2021, the current best practice is to use the ATMOS41 all-in-one weather sensor for air temperature monitoring, the standard deviation of the average temperature observed between our two stations indicates that they are comparable.

The precipitation and average temperature data from the two weather stations generally confirm the findings of Muita et al. (2021). In their study, they sought to demonstrate that electronically recorded data are of comparable quality to those recorded by a human observer and can therefore be used to fill data gaps.

Regarding solar radiation and relative humidity, the study found that the data collected at the two stations are significantly different (p = 0.000), with standard deviations of 92.498 and 2.373, respectively. This indicates significant dispersion, resulting in large variations in data around the mean. This could be explained by measurement errors during manual readings or by damage to or lack of maintenance of the automatic station.

Although the scattered nature of the data makes it difficult to draw firm conclusions, the strong positive correlations (r = 0.938) and (r = 0.820) for solar radiation and relative humidity, respectively, indicate that the values at both stations for these two parameters change in tandem.

The parameter values (precipitation, temperature, and solar radiation) from the conventional station are slightly higher than those from the automatic station, except for relative humidity, where the automatic station's values are higher. This means that the values from the conventional station, like those from the automatic station, may vary slightly from one another. Lukasova et al., 2024, who showed that analysis of monthly data revealed an underestimation of total precipitation in the AWS data, while AWS air temperature values were overestimated, made this observation.

Although automatic weather stations have the potential to improve the observation network, limited internet coverage results in missing data points, which affects the quality of data from these stations in Mexico. According to the WMO (2020) and Gabriel et al. (2021), this is due to high maintenance costs. Consequently, low-income countries lack the resources and trained personnel needed to maintain the automatic station (Sabatini, 2017, cited by Dombrowski).

Furthermore, the conventional station, although old, robust, and sensor-independent, inspires little confidence in the observed data among data collectors.

Both stations are necessary, and it would be desirable for them to be installed at every agricultural research site, as one or the other will be used to interpolate or verify values, and then exclude any outliers. Muita et al., 2021 report that ground-based station observations may contain certain uncertainties (especially when some data are missing); comparing them with AWS (automatic) data can bridge the gap and thus improve their quality and usability. This study therefore provides the means to improve the quality of the observational datasets available at the station.

5. Conclusion

This study shows that there is comparable consistency in most of the meteorological parameters examined between the two stations. A comparison of certain meteorological data for four parameters between the conventional station and the automatic station revealed considerable agreement. This demonstrates the performance and reliability of both weather stations (manual and automatic). Furthermore, using both weather stations is an advantage for agricultural research, as each can be used to fill in gaps, missing data, or outliers. The automatic weather station is more modern, accurate, and efficient for research and forecasting. Although it provides continuous data with a very low risk of error, it has its weaknesses. The conventional station, however, remains indispensable for verifying and ensuring the quality of automatic measurements.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare no conflicts of interest regarding the publication of this paper.

Author's contribution

The fifth author collected the data. The first author processed and drafted this article. The other authors read and corrected the manuscript. All the authors read and approved the final manuscript.

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