Accuracy of Remote XY Android App in Monitoring Compost NPK and Humidity Levels using HMI

Jerome V. Jocosol

Technological University of the Philippines

*Corresponding author's email: jeromejocosol.25@gmail.com

doi: https://doi.org/10.66133/5epddr63

ABSTRACT

This study evaluates the accuracy of the Remote XY application for monitoring compost parameters, using a Human–Machine Interface (HMI) as the reference standard, as it is directly connected to the compost being measured. Ten compost samples were tested, with readings recorded initially and remeasured after 24 hours under similar environmental conditions. Consistency between initial and repeated measurements was assessed using the Pearson Correlation Coefficient, while the Coefficient of Variation (CV) quantified relative variability in Remote XY readings. Results showed strong correlations for Nitrogen ($r = 0.97$), Phosphorus ($r = 0.98$), and Humidity ($r = 0.97$), indicating high reliability, with Potassium displaying a slightly lower yet strong correlation ($r = 0.85$). CV values ranged from the lowest in Humidity (22.04%) to the highest in Nitrogen (59.20%), reflecting relative stability or variability across parameters. These findings suggest that Remote XY provides readings largely consistent with the HMI, although Potassium measurements exhibited comparatively greater variation. The high correlation in key nutrient and humidity data supports the potential of Remote XY as a viable tool for continuous compost monitoring, enhancing process management and decision-making. Refinement in potassium detection could further improve overall accuracy, contributing to the optimization of IoT-based composting systems and enabling more efficient, data-driven waste-to-fertilizer processes

***Keywords**: compost monitoring, HMI, IoT-based agriculture, reliability testing, remote XY*

INTRODUCTION

Advances in the Internet of Things (IoT) have enabled real-time environmental monitoring through wireless sensor networks and mobile-based interfaces (Dhanaraju et al., 2022). In agricultural applications such as composting, accurate monitoring of parameters including nitrogen (N), phosphorus (P), potassium (K), temperature, humidity, and pH is essential for optimizing the decomposition process, maintaining nutrient quality, and improving operational efficiency (Băjenaru, Istrițeanu, & Ancuța, 2025). Composting is a controlled biological process that converts organic waste into nutrient-rich soil amendments, requiring a proper balance of raw materials, moisture, aeration, and carbon-to-nitrogen ratio to achieve efficient microbial activity and stable output (Hemidat et al., 2018).

Recent developments in smart agriculture have integrated IoT technologies to enhance compost monitoring through real-time data acquisition, logging, and visualization (Tomicic, 2023). Soil-integrated sensors connected to microcontrollers enable simultaneous transmission of data to multiple display platforms, such as hardware-based Human–Machine Interfaces (HMIs) and mobile applications (Yu et al., 2021). In addition, NPK sensors have demonstrated reliable performance in measuring soil nutrients, with only minimal variation compared to laboratory results (Adhikary, Choudhury, & Shankar, 2024), while humidity monitoring has been shown to be critical in maintaining optimal microbial activity during composting (Kim et al., 2015). Mobile applications such as the Remote XY dashboard provide a flexible and wireless means of visualizing sensor data through customizable Android interfaces (Cristea et al., 2023).

Despite these advancements, there is limited empirical evaluation of the performance of mobile-based monitoring platforms such as

Remote XY when compared to hardware-based HMIs. In composting applications, where real-time accuracy and consistency of data are critical, issues such as measurement discrepancies, latency, unstable connections, and unsynchronized updates may affect decision-making and process efficiency (Senadheera et al., 2024; Vrettos, Kazamias, & Lekkas, 2017; Hemidat et al., 2018). This indicates a need for systematic assessment of the accuracy and reliability of such mobile monitoring systems.

In this context, the problem addressed in this study is the lack of comparative evaluation between the Remote XY Android dashboard and hardware-based HMI in displaying real-time composting parameters. Specifically, it seeks to determine whether the Remote XY application can provide accurate, reliable, and synchronized readings comparable to those of a hardware interface.

The objectives of this study are to assess the performance of the Remote XY Android dashboard by comparing its readings with those of a hardware-based HMI connected to the same soil-integrated sensors. It specifically aims to: (1) compare the readings of nitrogen (N), phosphorus (P), potassium (K), and humidity between the two platforms; (2) determine latency and synchronization rates; (3) evaluate connection stability during continuous monitoring; (4) measure the occurrence of data dropouts or display errors; and (5) analyze the agreement and correlation between the readings obtained from both systems.

The findings of this study are expected to contribute to the improvement of IoT-based compost monitoring systems by providing insights into the reliability of mobile dashboard applications. It may benefit researchers, developers, and practitioners in smart agriculture by guiding the selection of appropriate monitoring interfaces and improving decision-making in compost management.

This study is limited to the evaluation of the Remote XY Android dashboard and a hardware-based HMI using the same soil-integrated sensors. It focuses only on selected composting parameters, namely nitrogen (N), phosphorus (P), potassium (K), and humidity, and evaluates system performance in terms of accuracy, latency, synchronization, connection stability, and data consistency. Other environmental parameters and external factors affecting composting are beyond the scope of this study.

METHODS

Research Design

This study employed an experimental design to evaluate the performance of a Remote XY-based soil sensor system for compost monitoring by comparing mobile application readings with a Human-Machine Interface (HMI) reference. Three performance aspects were tested: accuracy, assessed through Mean Absolute Percentage Error (MAPE) from ten samples; reliability, measured using Pearson's correlation on repeated measurements after 24 hours; and stability, evaluated through the Standard Deviation (SD) of five consecutive readings from a single sample.

Soil Integrated Sensor

To ensure high-fidelity data acquisition and fulfill requirements for experimental reproducibility, the study employed an integrated soil multi-parameter, featuring high-sensitivity 316L stainless steel probes, specifically selected for their corrosion resistance within the chemically active organic compost medium. As established in the framework proposed by Rifki and Lubis (2026) regarding multiparameter soil fertility monitoring systems based on the Internet of Things (IoT), this hardware configuration utilizes Frequency Domain Reflectometry (FDR) for moisture detection and advanced electrochemical analysis for nutrient quantification, interfaced via the RS485 Modbus RTU protocol to maintain signal integrity during transmission to both the Human–Machine Interface (HMI) and the Remote XY platform. The sensor provides a measurement range of 0–1999 mg/kg for Nitrogen, Phosphorus, and Potassium (NPK) and 0–100% for moisture content, with a precision resolution of 1 mg/kg and a calibrated accuracy of ±2% full scale. These technical specifications align with the physiological requirements of the composting process, where optimal moisture is typically maintained between 50% and 60%, and nutrient concentrations are monitored against baseline fertility standards to ensure a stabilized end-product. To mitigate the influence of external variables, all experimental trials were conducted under controlled environmental conditions, with an ambient temperature maintained at 25°C ± 2°C and atmospheric humidity at 65% ± 5%, ensuring that the observed variability in the Remote XY readings reflected the intrinsic performance of the IoT system rather than fluctuations in the surrounding climate.

HMI calibration

Prior to data collection, the Human–Machine Interface (HMI) monitoring system was subjected to functional verification using baseline reference readings to ensure operational stability. The monitoring setup was evaluated under controlled experimental conditions to reduce potential measurement bias and discrepancies between monitoring platforms. Although formal laboratory calibration procedures were not performed, measurement reliability was ensured through repeated measurements and controlled environmental settings during data acquisition. This procedure was implemented to maintain data consistency and to ensure that variations in readings were primarily associated with system performance and measurement analysis rather than external environmental or instrumental factors.

Procedures

To evaluate the performance of the Remote XY-based soil sensor system, three tests were conducted using compost samples, with readings from the mobile application compared to the Human-Machine Interface (HMI) display as the reference.

Accuracy Test

Ten compost samples were measured using both the HMI and the Remote XY app under identical conditions. The difference between the two readings for each sample was recorded, and the Mean Absolute Percentage Error (MAPE) was computed to determine the percentage difference from the reference (Prayudani et al., 2019).

Reliability Test

The same 10 compost samples were remeasured after 24 hours under similar environmental conditions. The Pearson Correlation Coefficient was used to check the consistency of readings between the initial and 24-hour measurements (Eisinga et al., 2013).

Stability Test

A single compost sample was measured five consecutive times using the Remote XY app. The Standard Deviation (SD) was calculated to determine the variation in repeated measurements (Abass et al., 2010).

Sampling Methods

A stratified random sampling approach was used to collect ten composite compost samples representing early, mid, and late decomposition stages. Each sample was prepared by combining subsamples from consistent depths and locations, homogenized, and labeled for measurement. Prior to data collection, the soil-integrated multiparameter sensor connected to the Human–Machine Interface (HMI) was subjected to basic functional verification to ensure stable readings under controlled environmental conditions. Sensor outputs were checked against baseline readings to confirm operational consistency before measurements were conducted. Data collected from the sensor were transmitted wirelessly through a microcontroller-based communication module to the Remote XY Android application, which served as the mobile monitoring interface for real-time visualization and data logging.

For the accuracy test, readings from the Remote XY app were compared with the HMI reference using Mean Absolute Percentage Error (MAPE). Reliability was assessed by remeasuring the same samples after 24 hours and calculating Pearson's correlation, while stability was evaluated through five consecutive readings of a representative sample using the Remote XY dashboard, with the standard deviation used to quantify variability. Although the study utilized 10 compost samples, which is suitable for preliminary experimental evaluation, the relatively small sample size is acknowledged as a limitation, and future studies may involve larger datasets to further validate system performance across broader compost conditions. This method ensured representative and consistent sampling, allowing valid comparisons between the mobile application and the hardware interface.

Materials

The study utilized soil-integrated sensors for real-time monitoring of compost parameters. Compost samples were placed in a compost bin, with data displayed on a hardware-based Human–Machine Interface (HMI) and wirelessly transmitted to a mobile phone via the Remote XY application for comparative analysis.

Experimental Setup

The experiment involved 10 compost samples of equal volume, each placed in a separate compost tub. Soil-integrated sensors were used to measure Nitrogen (N), Phosphorus (P), Potassium (K), and Humidity levels in each sample. A Human–Machine Interface (HMI) was connected directly to the compost sensors to serve as the reference standard for measurements. Simultaneously, the Remote XY mobile application was wirelessly connected to the same sensors, allowing real-time monitoring of the compost parameters on a mobile device. During each test, readings from the Remote XY interface were compared with the corresponding HMI measurements to evaluate the accuracy and reliability of the mobile application. Figure 1 illustrates the overall experimental setup with the compost tubs and sensor connections, while Figures 2, 3, and 4 show the interfacing of the Remote XY mobile application and HMI for real-time monitoring.

(**A**) Compost Samples (**B**) Soil Integrated Sensor

Figure 1. Experimental Setup

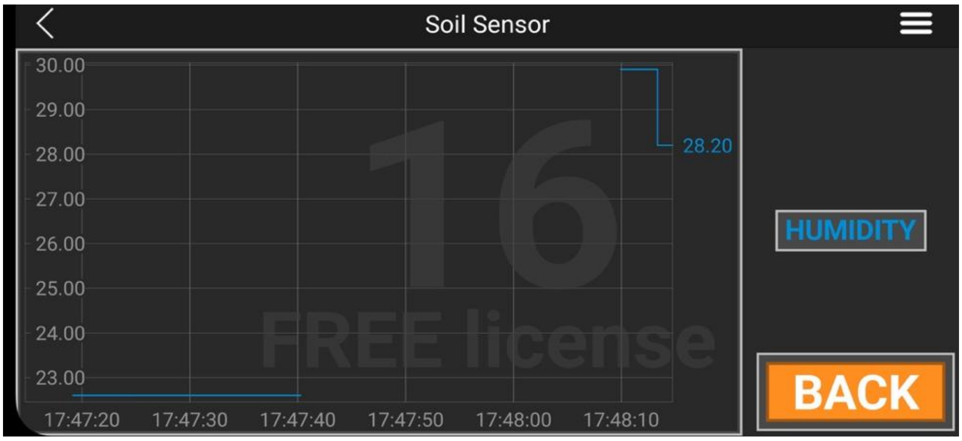

Figure 2. Remote XY Humidity Interface

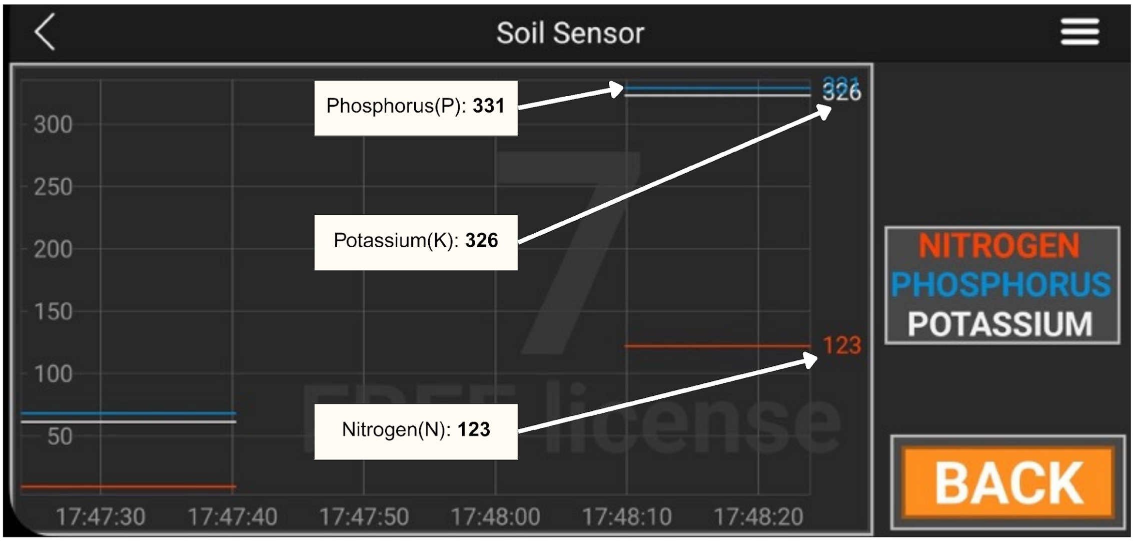

Figure 3. Remote XY NPK Level Interface

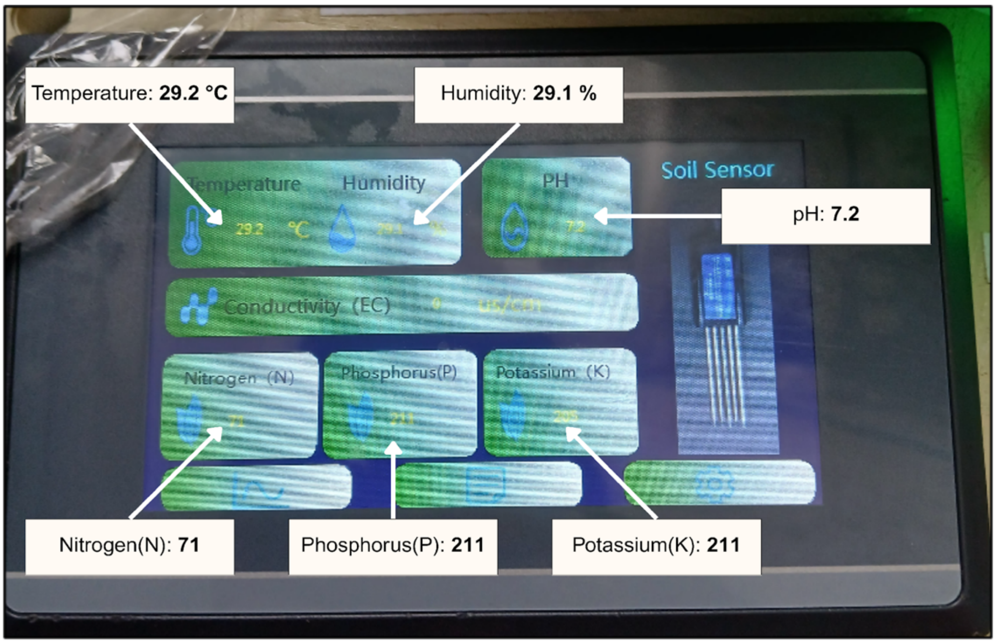

Figure 4. HMI Interface

RESULTS

Accuracy Test Results

The accuracy of the Remote XY Android application readings was evaluated by comparing them to the HMI reference values using the Mean Absolute Percentage Error (MAPE). Table 1 presents the gathered data during the testing. Results showed that humidity had the highest accuracy (3.90%), followed by phosphorus (5.41%), while potassium (8.33%) and nitrogen (9.06%) showed slightly higher discrepancies. These findings indicate that the Remote XY dashboard generally provides reliable readings, with humidity being the most precise and nitrogen showing the largest variation. The lower readings observed in certain trials, such as Trial #9 for nitrogen and phosphorus, may be attributed to natural compost heterogeneity, nutrient distribution variability within the compost matrix, and possible localized sensor positioning differences during measurement. Since compost is a biological and decomposing material, nutrient concentrations are not always uniformly distributed, which can result in fluctuations in sensor readings despite consistent environmental conditions.

Table 1. Accuracy Test Results

Trials	Compost Parameters	Human Interface Machine	Remote XY
1	Nitrogen	60	64
	Phosphorus	185	187
	Potassium	179	194
	Humidity	27.5	27.60
2	Nitrogen	59	59
	Phosphorus	182	183
	Potassium	175	177
	Humidity	35.3	34.90
3	Nitrogen	59	52
	Phosphorus	169	167
	Potassium	162	160
	Humidity	31.2	34.90
4	Nitrogen	79	79
	Phosphorus	230	229
	Potassium	223	223
	Humidity	28.6	28.20
5	Nitrogen	46	47
	Phosphorus	150	155
	Potassium	143	148
	Humidity	37.8	41.2
6	Nitrogen	43	43
	Phosphorus	147	146
	Potassium	140	139
	Humidity	22.9	22.9
7	Nitrogen	9	9
	Phosphorus	68	68
	Potassium	61	61
	Humidity	22.9	22.60
8	Nitrogen	122	123
	Phosphorus	329	331
	Potassium	323	326
	Humidity	28.7	28.20
9	Nitrogen	71	70
	Phosphorus	211	203
	Potassium	205	209
	Humidity	29.1	27
10	Nitrogen	34	11
	Phosphorus	125	72
	Potassium	188	65
	Humidity	22.3	21.2

Reliability Test Results

Table 2 presents the gathered data from both the Human–Machine Interface (HMI) and the Remote XY application during the remeasurement of the same ten compost samples after 24 hours under similar environmental conditions. The Pearson Correlation Coefficient was used to determine the degree of consistency between the initial and repeated measurements, while the Coefficient of Variation (CV) measured the relative variability in Remote XY readings. The results show a strong correlation for Nitrogen (r = 0.97), Phosphorus (r = 0.98), and Humidity (r = 0.97), indicating high reliability, with Potassium showing a slightly lower but still strong correlation (r = 0.85). CV values were lowest for Humidity (22.04%) and highest for Nitrogen (59.20%), reflecting the relative stability or variability in the readings. These findings suggest that Remote XY maintains consistent readings with HMI across most parameters, though Potassium readings exhibited comparatively more variation.

Table 2. Reliability Test Results

Parameter	Pearson R	CV (%)
Nitrogen	0.97	59.20
Phosphorus	0.98	54.23
Potassium	0.85	25.12
Humidity	0.97	22.04

Stability Test Results

Table 3 shows the gathered data for the stability test, where a single compost sample was measured five consecutive times using the Remote XY application. The Standard Deviation (SD) was computed for each parameter to assess measurement variation. Results show minimal variation across all parameters, with SD values of 0.71 for Nitrogen, Phosphorus, and Potassium, and an extremely low SD of 0.02 for Humidity. This indicates that Remote XY delivers highly stable readings under repeated measurements in a short time frame.

Table 3. Stability Test Results

Parameter	Read 1	Read 2	Read 3	Read 4	Read 5	SD
Nitrogen (%)	64.00	65.00	64.00	63.00	64.00	0.71
Phosphorus (%)	187.00	186.00	188.00	187.00	187.00	0.71
Potassium (%)	194.00	193.00	195.00	194.00	194.00	0.71
Humidity	27.60	27.55	27.58	27.61	27.60	0.02

CONCLUSION

This study assessed the Remote XY Android application's capability to monitor composting parameters through accuracy, reliability, and stability tests, with a hardware Human–Machine Interface (HMI) as the benchmark. Results showed that Remote XY closely matched HMI readings, with humidity achieving the highest accuracy (MAPE = 3.90%) and nitrogen showing the largest variation (9.06%). Reliability analysis revealed strong correlations across parameters, particularly for nitrogen ($r = 0.97$), phosphorus ($r = 0.98$), and humidity ($r = 0.97$), while potassium ($r = 0.85$) remained highly consistent but slightly less so. Coefficient of Variation analysis indicated that humidity had the lowest variability (22.04%) and nitrogen the highest (59.20%). Stability testing confirmed minimal short-term variation, with standard deviations of 0.71 for NPK and 0.02 for humidity.

Overall, Remote XY proved to be a reliable, accurate, and stable alternative to hardware HMIs, though nitrogen and potassium readings would benefit from further calibration. Although isolated outliers were observed in certain trials, such as sudden value drops in Trial 9, these were considered part of natural measurement variability in biological compost systems and did not significantly affect the overall reliability trends observed across the dataset. These discrepancies may also be partially attributed to limitations of multiparameter soil sensor technology, including sensitivity to localized nutrient concentration changes, as well as possible delays in wireless data synchronization between the microcontroller and the Remote XY mobile interface.

RECOMMENDATIONS

It is recommended to enhance the Remote XY platform by optimizing its data refresh rate, wireless communication stability, and synchronization protocols to improve real-time monitoring performance. Additional calibration between Remote XY and the hardware HMI is advised to further minimize reading discrepancies, particularly for nitrogen and potassium measurements. Future research may involve testing the monitoring system under different network conditions, integrating higher-precision soil nutrient sensors, and applying advanced calibration approaches such as machine learning–based correction models to further improve the accuracy and reliability of IoT-based compost monitoring systems.

Acknowledgments

The researcher would like to express sincere gratitude to the Technological University of the Philippines, College of Industrial Technology Graduate School, for its guidance and academic support throughout this study. Special thanks are also extended to the Computer Engineering students for their invaluable assistance in data collection, and to the urban backyard farmers who generously participated and provided compost samples essential to this research.

References

Adhikary, R., Choudhury, S. J., & Shankar, T. (2024). Real-time soil nutrient monitoring using NPK sensors: Enhancing precision agriculture. *International Journal of Experimental Research and Review, 45*(Spl. Vol.), 197–202. https://doi.org/10.52756/ijerr.2024.v45spl.015

Abass, S. M., Ibrahem, R. A., & Al-Khafaji, A. M. (2010). Effect of immersion in sodium chloride solution during microwave disinfection on dimensional stability, water sorption, and water solubility of denture base acrylic resin. *J Bagh College Dentistry, 22*(3)

Băjenaru, V.-D., Istrițeanu, S.-E., & Ancuța, P.-N. (2025). IoT-based environmental monitoring and agricultural applications. *Technologies, 13*(1), 38. https://doi.org/10.3390/technologies13010038

Cristea, O., Popa, N.-S., Manea, M.-G., & Popa, C. (2023). About the automation of an autonomous sail-propelled search drone. *Engineering, Technology and Applied Science Research.* https://doi.org/10.48084/etasr.6502

Dhanaraju, U., Chenniappan, P., Ramalingam, K., Pazhanivelan, S., & Kaliaperumal, R. (2022). Remote monitoring of agricultural parameters using IoT. *Agriculture, 12*(10), 1745. https://doi.org/10.3390/agriculture12101745

Hemidat, S., Jaar, M., Nassour, A., & Nelles, M. (2018). Monitoring of composting process parameters: A case study in Jordan. *Waste and Biomass Valorization, 9*(3). https://doi.org/10.1007/s12649-018-0197-x

Kim, E., Lee, D.-H., Won, S., & Ahn, H. (2015). Evaluation of optimum moisture content for composting of beef manure and bedding material mixtures using oxygen uptake measurement. *Asian-Australasian Journal of Animal Sciences, 29*(5), 753–758. https://doi.org/10.5713/ajas.15.0875

Kim, S., & Kim, H. (2016). A new metric of absolute percentage error for intermittent demand forecasts. *International Journal of Forecasting, 32*(3), 669–679. https://doi.org/10.1016/j.ijforecast.2015.12.003

Rifki, M. I., & Lubis, F. H. (2026). Multiparameter soil fertility monitoring system in agriculture based on the Internet of Things. *Journal of Computer Science and Informatics Engineering (CoSIE), 5*(1), 83–97.

Schober, P., Boer, C., & Schwarte, L. A. (2018). Correlation coefficients: Appropriate use and interpretation. *Anesthesia & Analgesia, 126*(5), 1763–1768. https://doi.org/10.1213/ANE.0000000000002864

Prayudani, S., et al. (2019). Analysis accuracy of forecasting measurement technique on random K-nearest neighbor (RKNN) using MAPE and MSE. *Journal of Physics: Conference Series, 1361*, 012089.

Tayman, J., & Swanson, D. A. (1999). On the validity of MAPE as a measure of population forecast accuracy. *Population Research and Policy*

Review, 18(4), 299–322. https://doi.org/10.1023/A:1006166418051

Tomicic, I. (2023). IoT-based agricultural compost monitoring system: Prototype development and sensor technology evaluation. *Journal name missing*, 1–14. https://doi.org/10.1080/1065657X.2023.2273845

Vrettos, G., Kazamias, G., & Lekkas, D. F. (2017). Smart compost monitoring system using open-source technologies. In *Proceedings of the 15th International Conference on Environmental Science and Technology*, Rhodes, Greece.

Yu, L., Gao, W., Shamshiri, R. R., Su, G., et al. (2021). Review of research progress on soil moisture sensor technology. *International Journal of Agricultural and Biological Engineering, 14*(4), 32–42. https://doi.org/10.25165/j.ijabe.20211404.6404