Development of a T-instrument for soil resistivity measurement in agricultural applications

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ABSTRACT

Geoelectric measurements are widely applied in natural resource exploration and groundwater studies. In this work, a prototype resistivity meter, referred to as the T-instrument, was developed for soil resistivity measurements in agricultural applications. The system is designed with an emphasis on portability, ease of operation, and field applicability. Measurements were conducted using the Wenner electrode configuration, and system performance was evaluated through comparison with a commercial resistivity meter (OYO McOhm). The results show a strong correlation coefficient of 0.96 between the two instruments, indicating good agreement. The instrument performs reliably within typical agricultural soil resistivity ranges and targets shallow soil depths relevant to crop root zones. However, further refinement is required to improve performance under high-resistivity conditions and optimize power efficiency.

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1. INTRODUCTION

Geophysical methods have been widely applied in Indonesia for subsurface characterization, including resource exploration, geological mapping, and environmental investigations [1]–[8]. Despite their extensive use in the energy and mining sectors, their application in agriculture remains relatively limited [9], [10]. In agricultural applications, several geophysical methods such as electrical resistivity, electromagnetic induction, and ground penetrating radar (GPR) can be employed to map spatial variations in soil fertility by quantifying the soil's physical parameters [9], [11]–[13]. From these measurements, fertility distribution maps can be developed to assist in optimizing irrigation systems and fertilizer applications. Currently, in most Indonesian agricultural practices, fertilizer application is conducted uniformly across entire fields, neglecting the inherent heterogeneity of soil properties. In reality, soil composition varies both laterally and vertically, influencing its capacity to retain nutrients and moisture [14], [15]. Consequently, homogeneous fertilization often leads to inefficiencies, including nutrient imbalance, wasted resources, and reduced crop yield [11], [16]. Among the available geophysical methods, electrical resistivity is particularly attractive for agricultural applications because it is sensitive to variations in soil moisture, texture, porosity, and ionic content, all of which influence soil fertility and crop productivity [11]–[13].

However, the implementation of geoelectrical resistivity surveys in agricultural areas encounters practical challenges [9], [17]. Conventional resistivity meters are typically time-consuming, requiring manual electrode relocation, and energy-intensive due to the heavy and bulky equipment involved. Moreover, high instrument costs limit accessibility for small-and medium-scale farmers. These constraints demonstrate the importance of developing a more efficient, lightweight, and affordable resistivity measurement system that is tailored to field conditions in Indonesia. Despite the growing application of geoelectrical methods in agriculture, studies focusing on low-cost and portable resistivity instruments specifically designed for rapid field-scale agricultural measurements remain limited. Several studies have reported the development of low-cost resistivity measurement systems for archaeological investigations and laboratory-scale research environments however, applications specifically targeting rapid agricultural field surveys remain relatively scarce [18], [19].

To address these limitations, this study proposes the development of a portable resistivity measurement prototype, referred to as the T-instrument. The design emphasizes portability, ergonomic usability, and cost-effectiveness, making it suitable for agricultural field applications. To evaluate its performance, the T-instrument was calibrated and compared with established instruments, namely the OYO McOhm and the Rigol DM3068. This comparison was conducted to assess the consistency of the measurements under both laboratory and field conditions. The scope of this study is limited to the development and calibration of the hardware prototype as an initial step toward the application of geoelectric methods in agricultural technology. Future work may explore the integration of resistivity measurements with other soil characterization approaches to provide broader insights into soil properties.

2. METHOD

2.1. Geoelectric measurement configuration

The geoelectric method measures subsurface resistivity by injecting electrical current into the ground through two current electrodes (C1 and C2) and measuring the resulting potential difference using two potential electrodes (P1 and P2). The electrodes are inserted into the ground at predetermined spacing (Figure 1). Increasing electrode spacing allows deeper current penetration into subsurface layers [20]. Several electrode configurations can be used depending on the measurement objectives. In this study, the Wenner configuration was employed, which consists of four collinearly arranged electrodes with equal spacing. This configuration was selected due to its simplicity, relatively strong signal response, and suitability for shallow subsurface investigations. In the Wenner configuration, the depth of investigation (DOI) is generally approximated as 0.5 to 1 time the electrode spacing. With an electrode spacing of 15 cm used in this study, the effective depth of investigation is estimated to range between approximately 7.5 cm and 15 cm. This depth range is particularly relevant for agricultural applications, as it corresponds to the active root zones of crops with significant nutrient uptake occurring in the upper soil layers. Therefore, the T-instrument is well suited for characterizing topsoil resistivity conditions that directly influence plant growth and soil fertility.

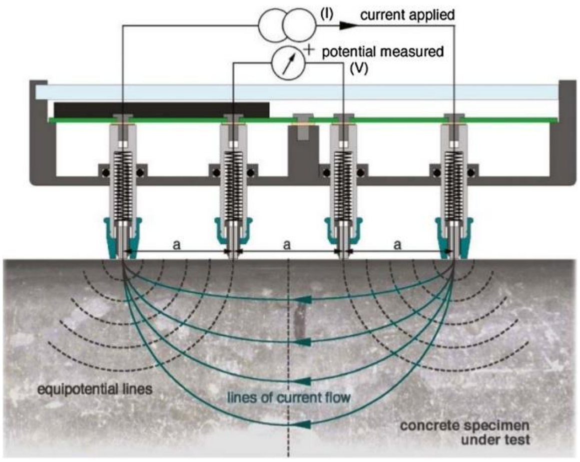


Figure 1. Schematic of Wenner configuration in geoelectric survey [21]

2.2. T-instrument design

The T-instrument was developed as a portable geoelectrical measurement device designed to efficiently map soil resistivity under agricultural field conditions. The instrument consists of four main components: a direct current (DC) power source, a voltmeter, an ammeter, and electrodes (Figure 2). The power source comprises 18650 lithium-ion batteries with a nominal voltage of 3.7 V and a fully charged voltage of 4.2 V per cell, each with a capacity of 2200 mAh. The batteries are arranged in a 3S5P configuration, resulting in a maximum output voltage of 12.6 V and a total capacity of 11,000 mAh. To generate the required measurement voltage, the 12 V DC power supply is stepped up to 230 V alternating current (AC) using a modified sine wave inverter. The AC output is then rectified using a diode-capacitor circuit, producing approximately 320 V DC. The rectifier circuit includes two 470 µF capacitors and an inductor as a noise filter.

The measurement subsystem employs a UNI-T 61B digital multimeter equipped with a 14-bit FS-9922 chip and an integrated analog-to-digital converter (ADC) for digital acquisition of voltage and current measurements. The circuit configuration was simulated using PSU designer software, demonstrating reduced noise and improved voltage stability after approximately one second at a current of 1 A. The measurement system is configured with the ammeter connected in series, while switches (SW1 and SW2) are used to reverse the current polarity, ensuring accurate and stable voltage readings. The potential difference between electrodes P1 and P2 is recorded by the voltmeter, and the resulting data are used to calculate apparent resistivity values. Copper-copper sulfate (Cu-$CuSO_4$) electrodes were employed to ensure stable electrode potentials and minimize polarization effects during measurements. The instrument frame is constructed from laminated polyvinyl chloride (PVC) produced by PT Rekatama, with an electrode spacing of 15 cm to optimize topsoil resistivity mapping (Figure 3). The high current requirement is primarily associated with the need to maintain sufficient signal penetration in resistive soils. However, this condition is not continuously sustained during measurements. Future work will focus on optimizing power efficiency and reducing power demand during measurements in high-resistivity environments.

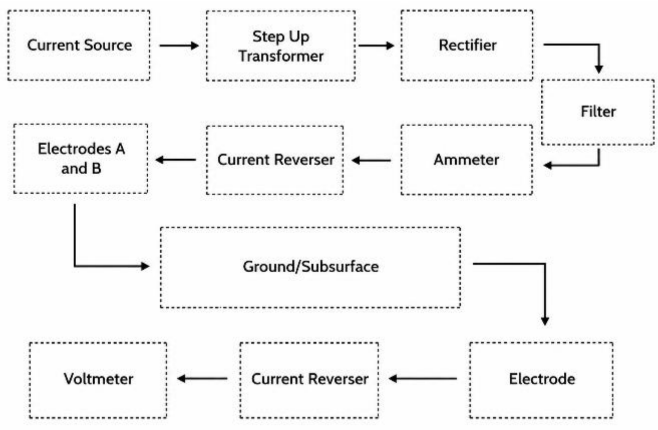


Figure 2. Block diagram of T-instrument

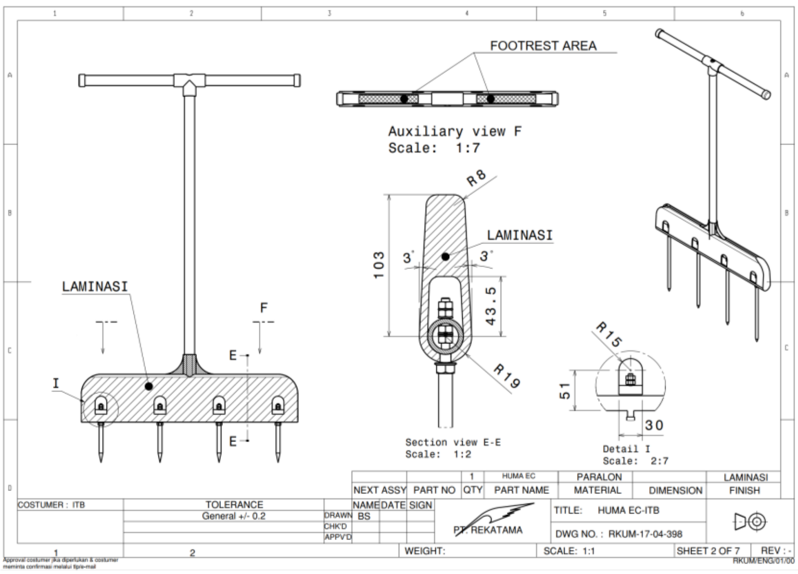


Figure 3. Technical drawing of the T-instrument

2.3. Field measurement and calibration

Field and laboratory tests were conducted to assess the performance of the T-instrument, with specifications as shown in Table 1, across various conditions. Field trials at the Seni Rupa field (Institut Teknologi Bandung-ITB campus), corn farmland (*Zea mays*), and Mr. C farmland (*Brassica rapa chinensis*) validated its functionality and endurance compared with the commercial OYO McOhm resistivity meter. Laboratory experiments using series-connected resistors and a RIGOL DM3068 4WR multimeter simulated high-resistance conditions and ensured calibration accuracy. To validate the measured values, the results were compared with soil resistivity values [22]. Overall, the T-Instrument demonstrated signal stability, reduced noise, and higher measurement resolution, confirming its reliability as a low-cost and portable resistivity measurement tool for agricultural applications.

Calibration was conducted through laboratory testing using controlled resistive loads and through field measurements under representative agricultural conditions. Instrument performance was evaluated by comparison with reference instruments (RIGOL DM3068 and OYO McOhm), while measurement consistency was assessed using correlation coefficients and repeated measurements. Detailed statistical analyses, such as confidence intervals and error margins, were beyond the scope of the present study and may be considered in future work. Instrument performance was assessed using correlation coefficients, which indicate the level of agreement between measurements obtained from the T-instrument and the reference instruments.

Table 1. Specification of the T-instrument

Specification	Range	Accuracy
DC voltage measurement	40 mV	+/- (0.8%+2.5)
	400 mV	+/- (0.8%+2.5)
	4 V / 40 V / 400 V	+/- (0.5%+2.5)
	1000 V	+/- (1.0%+2.5)
AC voltage measurement	40 mV	+/- (1.2%+4.5)
	400 mV	+/- (1.2%+4.5)
	4 V / 40 V / 400 V	+/- (1.5%+4.5)
	750 V	+/- (1.2%+4.5)
DC current measurement	400 µA / 4000 µA	+/- (1.5%+2.5)
	40 mA / 40 mA	+/- (1.2%+2.5)
	4 A / 10 A	+/- (1.5%+2.5)
AC current measurement	400 µA / 4000 µA	+/- (1.2%+4.5)
	40 mA / 400 mA	+/- (1.5%+4.5)
	4 A / 10 A	+/- (2.0%+4.5)
Resistance measurement	400 Ohm	+/- (1.2%+2.5)
	4 kOhm / 40 kOhm / 400 kOhm	+/- (1.5%+2.5)
	4 MOhm	+/- (1.2%+2.5)
	40 MOhm	+/- (1.5%+2.5)
Frequency	10 Hz~10 MHz	+/-(0.1%+4.5)
Frequency response	50 ~ 400 Hz	
Duty cycle	0.1% ~ 99.9%	
Power source (18650 Li-on battery, 3S5P)	Nominal voltage 3.7 V; maximum voltage 4.2 V; capacity 2200 mAh per cell (total capacity 11000 mAh)	
Step-up converter (modified sine wave inverter)	DC input 12 V; AC output 230 V	
Rectifier (diode-capacitor rectifier)	Full-wave rectifier using 4 diodes; 2×470 µF capacitors; inductor as noise filter	
DC output after rectification	~ 320 V DC	
Multimeter	UNI-T 61B multimeter equipped with a 14-bit FS-9922 chip and a built-in analog-to-digital converter (ADC) is integrated	
Electrodes	Cu-$CuSO_4$ non-polarizable	
Current reverse	Connected with the electrodes to reverse current polarity	

3. RESULTS AND DISCUSSION

Laboratory calibration (Table 1) demonstrates that the T-instrument provides highly consistent resistivity measurements compared to the reference device, RIGOL DM3068, with a correlation coefficient of $R = 0.99969$ (see Figure 4) [23]. This result confirms that the instrument is capable of accurately reproducing electrical responses under controlled conditions. Minor deviations at higher resistance values were observed, primarily due to reduced sensitivity in low-current measurements, which is a known limitation in resistivity systems. Additional laboratory tests using sand and soil media further demonstrated that the T-instrument successfully reproduced spatial resistivity distributions, although larger deviations were observed in sand media. Overall, the results confirm the instrument's reliability for laboratory-scale resistivity characterization, with some refinement still needed for high-resistance conditions.

Based on laboratory and field observations, the T-instrument provides reliable measurements within a resistivity range of approximately 10 to 200 Ω·m, which corresponds to typical agricultural soil conditions. Measurement deviations become more pronounced at higher resistivity values, particularly above this range, due to limitations in current injection and sensitivity at low current levels. This limitation is consistent with known challenges in resistivity measurements in dry or coarse-grained soils. Future work will focus on improving measurement accuracy in high-resistivity environments through enhanced current control and signal amplification.

Field testing was carried out to evaluate the performance and reliability of the T-instrument system under various soil conditions and to compare its measurements with those of the commercial OYO McOhm resistivity meter as a benchmark. The tests were conducted at three different locations: Seni Rupa field (ITB campus) (Figure 5(a)), corn farmland (*Zea mays*) (Figure 5(b)), and Mr. C's farmland (*Brassica rapa chinensis*) (Figure 5(c)) [24].

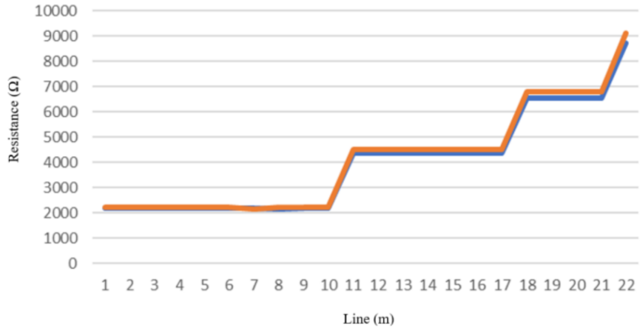
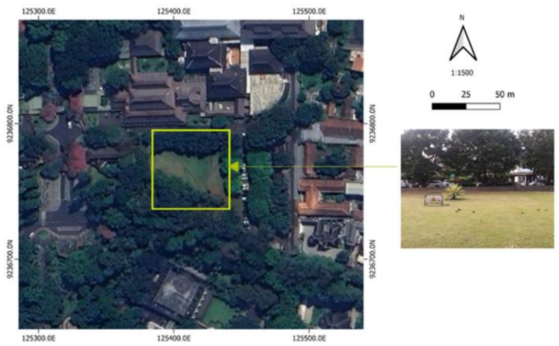
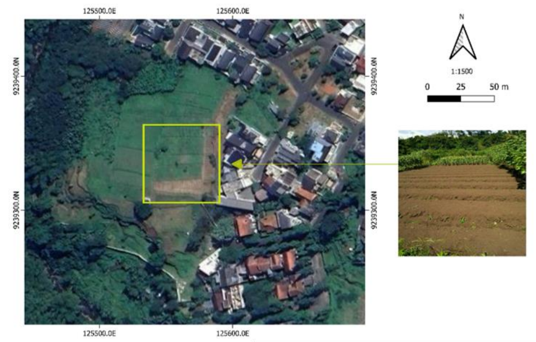


Figure 4. Graph of measurements using RIGOL DM3068 (blue) and the T-instrument (orange) on laboratory



(a)



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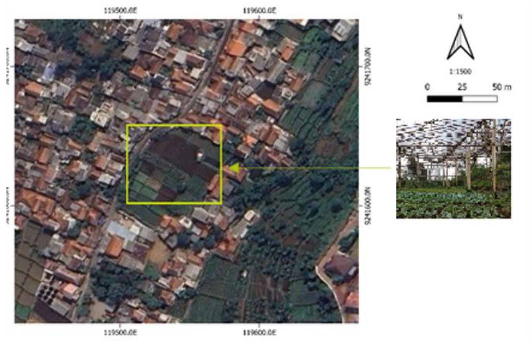


(c)

Figure 5. Survey site map: (a) Seni Rupa field, ITB, (b) corn (*Zea mays*) field, and (c) Mr. C (*Brassica rapa chinensis*) field

As shown in Figure 6(a), the measurements collected at the Seni Rupa field indicate moderately moist soil conditions, with resistivity values ranging from 12 Ω to 21 Ω. Using identical electrode configurations, the T-instrument yielded results that were consistent with the commercial instrument, producing correlation coefficients of $R = 0.88$ without self-potential (SP) correction and $R = 0.90$ with SP correction. This confirms that SP correction significantly improves the accuracy of resistivity measurements [25]. Mechanically, the instrument operated reliably, although minor issues, such as PVC joint detachment were observed during field handling.

Figure 6(b) shows the comparison results obtained from the corn farmland site. Soil resistivity in this area ranged between 8 Ω and 28 Ω. A total of 351 measurement points was collected to compare the T-instrument with the OYO McOhm system. The resulting correlation coefficient of $R = 0.9164$ demonstrates that T-instrument was capable of accurately reproducing the resistivity trend measured by the benchmark device. However, several limitations were noted, including high power consumption and occasional PVC frame cracking, indicating the need for further refinement in mechanical and electrical design [26].

The final field test, carried out at Mr. C's farmland, recorded resistivity values between 30 and 64 Ωm (Figure 6(c)). Measurements collected by the T-Instrument closely matched those recorded by the OYO McOhm, achieving a correlation coefficient of $R = 0.99430$. Structurally, the instrument performed well, allowing easy and ergonomic electrode penetration. However, the large electronic enclosure raised the center of mass and made handling less stable, while the flexible PVC frame indicated the need for further reinforcement [27]. In addition, Figure 7 presents resistivity mapping results obtained using T-instrument (Figure 7(a)) and the RIGOL DM3068 (Figure 7(b)).

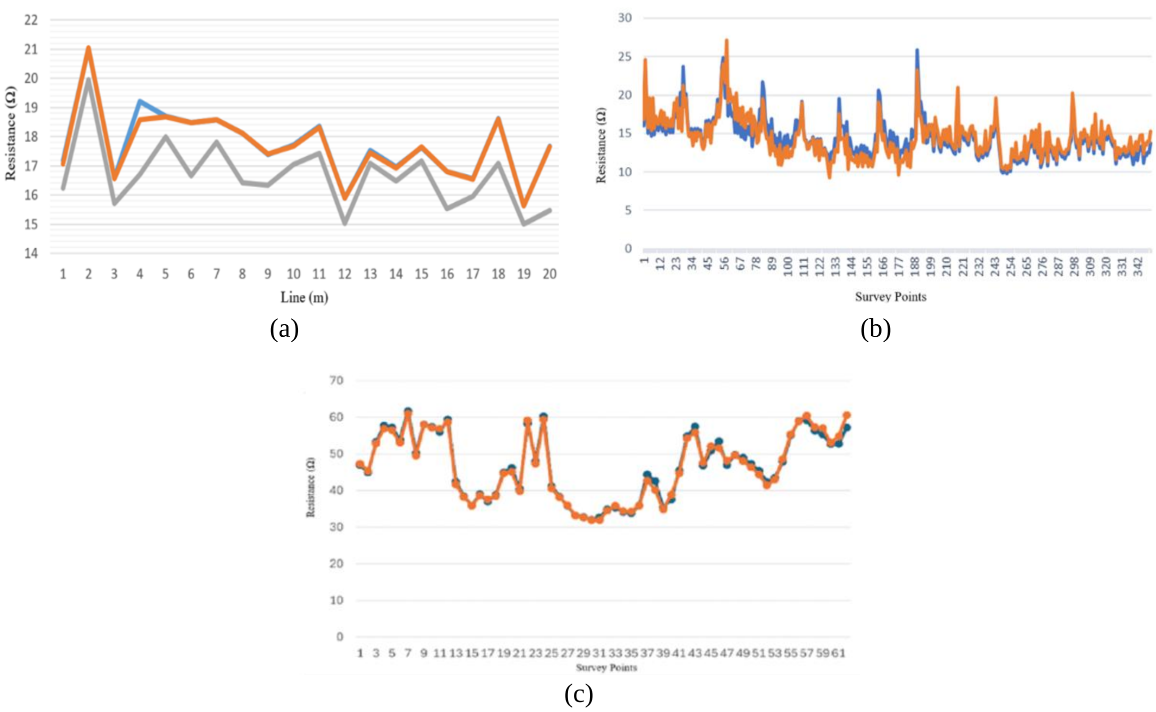
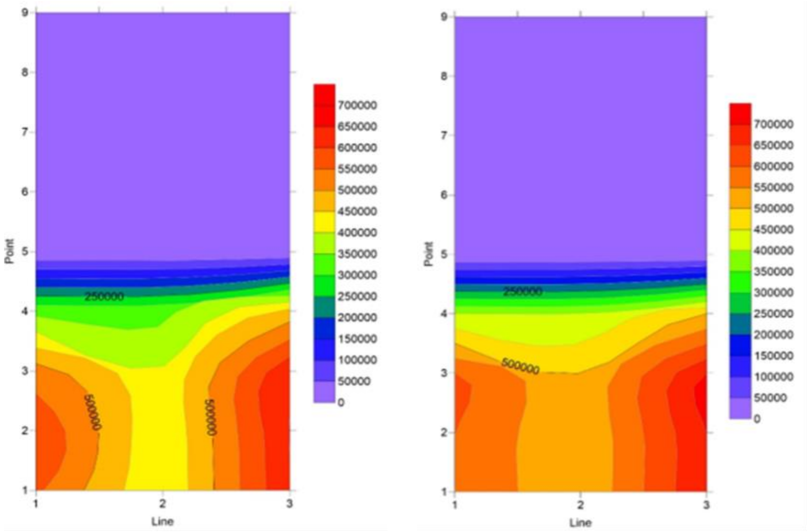


Figure 6. Graph of measurements using: (a) OYO McOhm (gray) and the T-instrument (blue with SP and without SP at Seni Rupa field, ITB; (b) OYO McOhm (blue) and the T-instrument (orange) on corn (*Zea mays*) field; and (c) OYO McOhm (blue) and T-instrument (orange) in Mr. C (*Brassica rapa chinensis*) field

The results from both laboratory and field test indicate that the T-instrument shows consistent performance and good agreement with reference measurements for agricultural applications, supporting the increasing need for accurate soil electrical property assessment in precision agriculture [27]–[30]. The integration of SP correction, improved voltage regulation, and signal filtering contributes to enhanced measurement stability [30]. These findings are consistent with the laboratory calibration results discussed earlier. From a mechanical perspective, the current prototype demonstrates functional usability but still requires structural improvements for better durability under field conditions. The observed issues, including joint detachment and frame flexibility, suggest that future designs should incorporate more robust materials and improved structural configurations. The fixed Wenner array configuration simplifies electrode deployment and reflects a standard configuration for shallow resistivity mapping [21]. The modular electrodes and ergonomic improvements reduce operator fatigue and support consistent soil contact, which is important for reliable resistivity measurements in varying soil textures and moisture conditions [28]. Some limitations remain, such as weight distribution due to the large electronic housing and significant power requirements for certain high-current measurements.



(a) (b)

Figure 7. Resistivity mapping results: (a) the T-Instrument and (b) RIGOL DM3068

Laboratory simulations further confirm the ability of the device to capture resistivity trends across different media [11], [22]. These limitations are consistent with challenges in low-current measurements, particularly in high-resistivity conditions need for further calibration improvements. The integration of real-time recording and processing supports efficient soil mapping, reinforcing the relevance of portable sensors in modern precision agriculture [23]. From an application standpoint, T-instrument offers clear advantages over traditional geoelectrical tools, which are often heavy and designed for deep subsurface exploration rather than agricultural root-zone assessment [30]. By providing rapid and reliable resistivity measurements within shallow subsurface depths relevant to agricultural applications, the system can aid site-specific agricultural practices such as irrigation planning, nutrient management, and soil amendment decisions [27], [28]. Its simplicity allows effective operation even by non-specialist users, supporting broader technology adoption among farmers and field practitioners [23]. The T-instrument represents an early-stage prototype with strong potential for development into a practical soil resistivity measurement tool. The soil resistivity information generated by the T-instrument may assist in identifying spatial variations in soil conditions within agricultural fields. Such information can support decisions related to irrigation management, fertilizer application, and soil amendment practices. Previous studies have demonstrated the feasibility of developing low-cost resistivity measurement systems for archaeological investigations and laboratory-scale electrical resistivity tomography applications [18], [19]. The present study applies a similar low-cost instrumentation approach to agricultural field conditions, with an emphasis on portability, rapid deployment, and practical operation for soil characterization. A comparison between the T-instrument and conventional resistivity meters is presented in Table 2.

Despite the encouraging results, several limitations remain in the current prototype. The instrument may require relatively high power under certain measurement conditions, the PVC-based frame still requires structural reinforcement for long-term field durability, and measurement accuracy decreases in high-resistivity soils due to limitations in low-current detection. Future improvements may include power optimization, structural reinforcement, enhanced performance in high-resistivity environments, and the development of stability analysis, error-compensation, and adaptive calibration approaches. In addition, the generated soil resistivity data may support future integration with wireless sensor networks (WSN) and internet of things (IoT)-based precision agriculture systems. Such integration could facilitate more efficient irrigation planning, fertilizer management, and soil amendment strategies at the field scale.

Table 2. Comparative table for T-instrument with conventional resistivity meter

Aspect	Conventional resistivity systems	Proposed T-instrument
Portability	Generally bulky and heavy	Portable prototype
Cost	Relatively expensive	Low-cost design
Deployment	Manual and time-consuming	Simplified field deployment
Target application	General geophysical surveys	Agricultural soil characterization
Electrode configuration	Various configurations	Fixed Wenner array (spacing 15 cm)
Depth of investigation	Variable depending on survey objective	Shallow topsoil (7.5-15 cm)

4. CONCLUSION

The T-instrument demonstrates good agreement with reference instruments, with correlation coefficients of 0.99 compared to the OYO McOhm and 0.99 compared to the RIGOL DM3068, confirming its capability for soil resistivity measurement under laboratory and field conditions. The system is designed for portable, short-duration field measurements and is particularly suitable for characterizing shallow soil layers (approximately 7.5–15 cm), which are relevant to agricultural root zones. Despite these advantages, the current prototype still has several limitations. The system may require high current under certain conditions, and measurement accuracy decreases in high-resistivity soils. In addition, mechanical improvements are needed to enhance structural durability. These findings demonstrate that the T-instrument has strong potential as a practical and low-cost solution for agricultural soil characterization, while further improvements in power efficiency, structural durability, and high-resistivity performance will enhance its applicability under a wider range of field conditions. Future work will focus on improving the instrument design through electronics miniaturization, integration of wireless data transmission, validation across a wider range of soil conditions, and the combination of resistivity measurements with complementary soil parameters to support more comprehensive agricultural soil characterization.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author, TS.

REFERENCES

[1] M. Marwan *et al.*, "Investigation of Geothermal Resources Using Magnetotelluric Method in Jaboi, Indonesia," *Geosciences (Switzerland)*, vol. 16, no. 2, p. 58, Jan. 2026, doi: 10.3390/geosciences16020058.
[2] Y. Dianwiyono and D. P. Wiradityo, "Optimization Of Geophysical Design Survey Priority Areas For Unconventional Oil And Gas Exploration Using Topex Gravity Data Analysis," *Jurnal Pendidikan Indonesia*, vol. 6, no. 10, pp. 4617–4633, 2025, doi: 10.59141/japendi.v6i10.8697.
[3] M. Kadri, T. Tampubolon, J. Hutahaean, N. M. Muztaza, and M. N. M. Nordin, "Utilizing of Geophysical Methods for Geothermal Exploration at Guru Kinayan Village, Tanah Karo Regency," *Jurnal Penelitian Pendidikan IPA*, vol. 11, no. 1, pp. 367–373, Jan. 2025, doi: 10.29303/jppipa.v11i1.9881.
[4] A. K. Permana, R. Setiawan, G. M. L. Junursyah, D. Yurnaldi, E. Y. Patriani, and A. Setiawan, "Review of Geological Framework and Hydrocarbon Potential of the Banyumas Basin," *Jurnal Geologi dan Sumberdaya Mineral*, vol. 25, no. 4, pp. 249–257, 2024.
[5] C. Wahyuningrum, "Optimization Of Hydrocarbon Exploration And Production Through Geophysical Data Integration And Reservoir Model Validation," *Jurnal Jaring SainTek*, vol. 6, no. 2, pp. 57–64, 2024, doi: 10.31599/nda0wa43.
[6] W. Juwita, J. Juventa, A. M. Setiawan, A. A. Martha, N. Hudayat, and B. Sutejo, "Identification of potential hydrocarbon traps using the gravity method in the Bengkulu basin," *Iranian Journal of Geophysics*, vol. 18, no. 3, pp. 69–83, 2024, doi: 10.30499/IJG.2023.409882.1535.
[7] K. Haritha, "A Review of Recent Advancements in Geophysical Technologies and Their Implications for Mineral and Hydrocarbon Exploration," *ASEAN Journal for Science and Engineering in Materials*, vol. 2, no. 2, pp. 95–108, 2023.
[8] D. Purba *et al.*, "Resource Assessment Methods Selection for Geothermal Exploration Project in Indonesia: What Are the Considerations?," *Proceedings, 46th Workshop on Geothermal Reservoir Engineering*, vol. 46, pp. 1–10, 2021.
[9] Widodo, A. Salam, N. Y. Azhari, F. D. Fachrezi, M. R. Fadhillah, and A. Nurbaity, "Shallow Geophysical Methods for Agricultural Land Characterization: Investigating Soil Physical Parameters for Precision Farming in Ciumbuleuit," *IOP Conference Series: Earth and Environmental Science*, vol. 1458, no. 1, 2025, doi: 10.1088/1755-1315/1458/1/012014.
[10] A. Darul, D. E. Irawan, and E. Agustine, "Geophysics for the environment in Indonesia," *F1000Research*, vol. 13, p. 131, Feb. 2024, doi: 10.12688/f1000research.145869.1.
[11] O. T. Kayode, A. P. Aizebeokhai, and A. M. Odukoya, "Geophysical and contamination assessment of soil spatial variability for sustainable precision agriculture in Omu-Aran farm, Northcentral Nigeria," *Heliyon*, vol. 8, no. 2, p. e08976, Feb. 2022, doi: 10.1016/j.heliyon.2022.e08976.
[12] V. Parashar and B. Mishra, "Designing efficient soil resistivity measurement technique for agricultural wireless sensor network," *International Journal of Communication Systems*, vol. 34, no. 8, May 2021, doi: 10.1002/dac.4785.
[13] J. P. Smedema, P. Van Paassen, M. J. P. G. Van Kroonenburgh, G. Snoep, H. J. G. M. Crijns, and J. W. C. Tervaert, "Cardiac involvement of Churg Strauss syndrome demonstrated by magnetic resonance imaging," *Clinical and Experimental Rheumatology*, vol. 22, no. 6 SUPPL., pp. S75–S78, 2004.
[14] M. C. Leewis *et al.*, "The influence of soil development on the depth distribution and structure of soil microbial communities," *Soil Biology and Biochemistry*, vol. 174, p. 108808, Nov. 2022, doi: 10.1016/j.soilbio.2022.108808.
[15] I. Comte, "Landscape-scale assessment of soil properties , water quality and related nutrient fluxes under oil palm cultivation : a case study in Sumatra, Indonesia," *Agriculture, Ecosystems & Environment*, vol. 169, pp. 58–68, 2013.
[16] M. Zaib *et al.*, "A Review on Challenges and Opportunities of Fertilizer Use Efficiency and Their Role in Sustainable Agriculture with Future Prospects and Recommendations," *Curr Rese Agri Far*, vol. 4, no. 4, pp. 1–14, 2023, doi: 10.18782/2582-7146.201.
[17] A. Alhassan, A. Aliyu, A. Magaji, M. N. Abdulkareem, and M. Abdullahi, "An Insight Into The Importance Of Application Of Geophysical Methods In Agriculture For National Economic Development," *Global Sustainability Research*, vol. 1, no. 1, pp. 1–4, Aug. 2022, doi: 10.56556/gssr.v1i1.301.
[18] M. de la Vega, M. V. Bongiovanni, and V. Grünhut, "Design of a Low-Cost Electrical Resistivity Meter for Near Surface Surveys," *Earth and Space Science*, vol. 8, no. 12, Dec. 2021, doi: 10.1029/2020EA001575.
[19] N. Delmonte, D. Spaggiari, G. Chiorboli, C. Fagandini, and A. Zanini, "An electrical resistivity tomography system for imaging at laboratory scale," *Measurement: Journal of the International Measurement Confederation*, vol. 252, p. 117366, Aug. 2025, doi: 10.1016/j.measurement.2025.117366.
[20] E. Rolia and D. Sutjiningsih, "Application of geoelectric method for groundwater exploration from surface (A literature study)," in *AIP Conference Proceedings*, 2018, p. 020018. doi: 10.1063/1.5042874.
[21] M. Cheytani and S. L. I. Chan, "The applicability of the Wenner method for resistivity measurement of concrete in atmospheric conditions," *Case Studies in Construction Materials*, vol. 15, p. e00663, Dec. 2021, doi: 10.1016/j.cscm.2021.e00663.
[22] M. Kižlo and A. Kanbergs, "The Causes of the Parameters Changes of Soil Resistivity," *Scientific Journal of Riga Technical University Power and Electrical Engineering*, vol. 25, no. 25, pp. 43–46, Jan. 2010, doi: 10.2478/v10144-009-0009-z.
[23] A. Suprem, N. Mahalik, and K. Kim, "A review on application of technology systems, standards and interfaces for agriculture and food sector," *Computer Standards and Interfaces*, vol. 35, no. 4, pp. 355–364, Jun. 2013, doi: 10.1016/j.csi.2012.09.002.
[24] A. McCauley, C. Jones, and J. Jacobsen, "Soil and Water Management: Basic Soil Properties," *Soil and Water*, pp. 994–2721, 2005, [Online]. Available: http://landresources.montana.edu/SWM/PDF/Final_proof_SW1.pdf
[25] A. Q. Nguyen, G. Klysz, F. Deby, and J. P. Balayssac, "Evaluation of water content gradient using a new configuration of linear array four-point probe for electrical resistivity measurement," *Cement and Concrete Composites*, vol. 83, pp. 308–322, Oct. 2017, doi: 10.1016/j.cemconcomp.2017.07.020.
[26] J. M. Anderson and B. N. Richards, "Introduction to the Soil Ecosystem," *The Journal of Animal Ecology*, vol. 45, no. 1, p. 327, May 1976, doi: 10.2307/3784.
[27] A. Abbas, S. Khan, N. Hussain, M. A. Hanjra, and S. Akbar, "Characterizing soil salinity in irrigated agriculture using a remote sensing approach," *Physics and Chemistry of the Earth*, vol. 55–57, pp. 43–52, Jan. 2013, doi: 10.1016/j.pce.2010.12.004.
[28] C. K. Johnson, J. W. Doran, H. R. Duke, B. J. Wienhold, K. M. Eskridge, and J. F. Shanahan, "Field-Scale Electrical Conductivity Mapping for Delineating Soil Condition," *Soil Science Society of America Journal*, vol. 65, no. 6, pp. 1829–1837, 2001, doi: 10.2136/sssaj2001.1829.
[29] D. L. Corwin and S. M. Lesch, "Apparent soil electrical conductivity measurements in agriculture," *Computers and Electronics in Agriculture*, vol. 46, no. 1-3 SPEC. ISS., pp. 11–43, Mar. 2005, doi: 10.1016/j.compag.2004.10.005.
[30] B. J. Allred, J. J. Daniels, and M. R. Ehsani, *Handbook of agricultural geophysics*. Boca Raton, FL, USA: CRC Press, 2008. doi: 10.1201/9781420019353.

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