ABSTRAK

KALIBRASI DAN VALIDASI MULTI SENSOR RS485 TERHADAP HASIL PENGUKURAN LABORATORIUM

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Multi sensor RS485 berbasis komunikasi Modbus RTU merupakan instrumen portabel yang mampu mengukur parameter tanah secara real-time di lapangan. Namun, akurasi pembacaan sensor terhadap nilai referensi laboratorium perlu diverifikasi melalui proses kalibrasi sebelum dapat digunakan sebagai dasar pengambilan keputusan dalam pertanian presisi. Penelitian ini bertujuan untuk: (1) mengkuantifikasi perbedaan pembacaan sensor RS485 terhadap nilai referensi laboratorium; (2) membangun model kalibrasi regresi linear Y = a + bX untuk parameter pH dan EC; dan (3) mengevaluasi akurasi sensor menggunakan indikator R^2, MAPE, dan RMSE. Penelitian dilaksanakan di Laboratorium Mekanisasi, Fakultas Teknologi Pertanian, Universitas Kristen Artha Wacana Kupang, pada bulan Desember 2025. Kalibrasi dilakukan terhadap larutan buffer pH standar (4,00; 7,00; 10,00) dan larutan standar EC (84; 1.413; 12.880 µS/cm), masing-masing dengan tiga kali pengulangan, menghasilkan 18 pasang data. Analisis regresi linear dilakukan menggunakan Microsoft Excel, dan akurasi dievaluasi berdasarkan kriteria R^2 dan MAPE. Hasil penelitian menunjukkan bahwa sensor pH memiliki akurasi sangat tinggi dengan persamaan kalibrasi Y = 0,0359 + 0,9996X (R^2 = 0,9996; MAPE = 0,48%; RMSE = 0,058 unit pH; akurasi 99,52%). Nilai slope mendekati 1 dan intercept mendekati 0 mengindikasikan tidak adanya gain error dan systematic bias yang berarti. Untuk sensor EC, diperoleh persamaan Y = 2,5487X − 863,036 (R^2 = 0,9865; MAPE = 32%; RMSE = 4.369 µS/cm). Analisis per titik konsentrasi mengungkap ketimpangan akurasi yang signifikan: pada EC 1.413 µS/cm error hanya 12–13% (kategori baik), sedangkan pada EC 12.880 µS/cm error mencapai 58–60% (kategori buruk) akibat saturasi respons sensor pada konsentrasi ion tinggi. Disimpulkan bahwa sensor RS485 layak digunakan langsung untuk pengukuran pH tanah di lapangan dengan akurasi 99,52%. Untuk parameter EC, sensor direkomendasikan digunakan pada rentang ≤ 2.000 µS/cm setelah dikoreksi dengan persamaan kalibrasi, dan memerlukan pengembangan model kalibrasi non-linear untuk konsentrasi di atas rentang tersebut.

Kata kunci: kalibrasi sensor, multi sensor RS485, pH tanah, electrical conductivity, regresi linear, MAPE, RMSE

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ABSTRACT

CALIBRATION AND VALIDATION OF RS485 MULTI-SENSOR AGAINST LABORATORY MEASUREMENT RESULTS

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The RS485 multi-sensor, based on Modbus RTU communication protocol, is a portable instrument capable of measuring soil parameters in real-time in the field. However, the accuracy of sensor readings relative to laboratory reference values must be verified through calibration before the device can be used as a reliable basis for precision agriculture decisions. This study aimed to: (1) quantify the difference between RS485 sensor readings and laboratory reference values; (2) develop a linear regression calibration model Y = a + bX for pH and EC parameters; and (3) evaluate sensor accuracy using R^2, MAPE, and RMSE indicators. The study was conducted at the Mechanization Laboratory, Faculty of Agricultural Technology, Universitas Kristen Artha Wacana Kupang, in December 2025. Calibration was performed using standard pH buffer solutions (4.00, 7.00, 10.00) and standard EC solutions (84, 1,413, and 12,880 µS/cm), each with three repetitions, yielding 18 data pairs. Linear regression analysis was performed using Microsoft Excel. Accuracy was evaluated based on R^2 and MAPE. Results showed that the pH sensor achieved very high accuracy with the calibration equation Y = 0.0359 + 0.9996X (R^2 = 0.9996; MAPE = 0.48%; RMSE = 0.058 pH units; accuracy 99.52%). A slope near 1 and intercept near 0 indicated no significant gain error or systematic bias. For the EC sensor, the calibration equation Y = 2.5487X − 863.036 was obtained (R^2 = 0.9865; MAPE = 32%; RMSE = 4,369 µS/cm). Concentration-specific analysis revealed a significant accuracy gap: at EC 1,413 µS/cm the error was only 12–13% (good category), while at EC 12,880 µS/cm the error reached 58–60% (poor category), attributed to sensor response saturation at high ion concentrations. It is concluded that the RS485 sensor is suitable for direct field use in measuring soil pH with 99.52% accuracy. For EC measurement, the sensor is recommended for use within the ≤ 2,000 µS/cm range after applying the calibration equation. Development of a non-linear calibration model is recommended for concentrations exceeding this range.

Keywords: sensor calibration, RS485 multi-sensor, soil pH, electrical conductivity, linear regression, MAPE, RMSE

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