Journal of Soft Computing Exploration

Homepage: https://shmpublisher.com/index.php/joscex

p-ISSN: 2746-7686
e-ISSN: 2746-0991

.

Application of the KNN method to check soil compatibility using a microcontroller for android-based banyuwangi citrus fruit plants

Solehatin[1], Hadiq[2], Dwika Ananda Agustina Pertiwi[3]
[1]Informatics Management, Sekolah Tinggi Ilmu Komputer PGRI Banyuwangi, Indonesia
[2]Information Technical, Sekolah Tinggi Ilmu Komputer PGRI Banyuwangi, Indonesia
[3]Department of Technology Management, Universiti Tun Hussein Onn Malaysia, Malaysia

Article Info

Article history:

Received August 20, 2023
Revised September 19, 2023
Accepted September 20, 2023

Keywords:

First keyword
Second keyword
Third keyword
Fourth keyword
Fifth keyword

ABSTRACT

The city of Banyuwangi needs a touch of information technology in the agricultural sector, namely in the process of planting orange fruit, because orange fruit planting is carried out continuously to meet export needs. Citrus fruit planting is sometimes carried out without paying attention to the existing soil nutrient content, this condition can result in less than optimal harvest results. The research was carried out by creating a soil nutrient detection application with the aim of providing information to farmers about the soil nutrient content including nitrogen, calcium, phosphorus, pH and moisture resistance before planting citrus fruit. From the results of trials conducted by researchers with farmers based on various types of soil used as trial data, the information shows a match of 89.6%. The results of the research produced an Android-based soil nutrient checking application that farmers can use to check soil nutrients when planting citrus fruit. In conducting the research, the researcher created an application by applying the KNN method and utilizing a microcontroller to input the data. By combining methods and tools, microcontrollers can assist the implementation process so as to provide information in the form of soil suitability for planting citrus fruit based on the nutrient content of the soil being examined. The contribution made from the research results is the application of a KNN method which is used to check soil nutrients so that it can maximize the results of the detection carried out. Meanwhile, another contribution is the use of a tool in the form of microcontroller which is used to automatically input data which can be obtained using the Bluetooth service in the soil nutrient check application.

Corresponding Author:

Solehatin,
Informatics Management,
Sekolah Tinggi Ilmu Komputer PGRI Banyuwangi,
Jalan Achmad Yani Nomor 80 Taman Baru Banyuwangi, Jawa Timur, Indonesia.
Email: atin33@yahoo.ac.id
https://doi.org/10.52465/joscex.v4i3.197

1. INTRODUCTION

Banyuwangi is a producer of citrus fruit which is classified as the largest contributor to the harvest in East Java [1]. Besides being famous as a rice barn in East Java, Banyuwangi is currently also a center for orange production in East Java. Until now, the orange harvest area in Banyuwangi covers 3,695.34 hectares. With orange production reaching 65,145.16 tons. With an average productivity of oranges in Banyuwangi, 172.93 quintals per hectare [2]. The achievement of citrus productivity in Banyuwangi is quite promising for citrus farmers.

And currently Banyuwangi district is one of the citrus centers in Indonesia that has implemented Bujangseta technology [3]. It is hoped that all domestic citrus growers will apply this technology. Because with Bujangseta, oranges have premium quality with relatively low production costs. The Bujangseta Technology concept is that oranges can bear fruit all year round (off season) and produce uniform premium quality fruit, market-appropriate flavors (sweet and sour), smooth fruit skin at an adequate price [4], [5].

In planting citrus fruits what farmers need is to know the land or soil that will be used for planting, there have been discoveries to find out the color of a soil. The results of research [6] are that an E-Soil application can be used to assist farmers in identifying soil color on an Android-based basis that uses the Munsell Soil Color Chart and can be accessed on Google Play. soil color, latitude and longitude coordinates, detects soil color with the Munsell Soil Color Chart (MSCC) notation and integrates with the Spatial Information Web [7], [8].

Apart from the soil element, fertilization also affects the successful process of planting citrus fruits [9]. The results of the analysis show that the fertilizer treatment based on soil analysis both with and without pruning was significantly different from other treatments at the level of confidence and produced the highest number of fruit, while the fertilizer treatment based on the yields transported produced the smallest number of fruit (33.75 and 69 fruit) . Meanwhile, the smallest fruit weight and diameter resulted from the application of farmer's fertilizer doses combined with pruning treatment [10], [11].

Apart from the color of the soil, the elements of fertilization and pruning, the things that need to be considered in planting citrus fruits, there are other things that a farmer can pay attention to, namely the elements of plant nutrition and evaluation of soil fertility in citrus plantations [12]. The low status of soil fertility in citrus plantations at locations C2 and C3 is due to the limiting soil chemical properties, namely the low soil C-organic content. This is understandable because the presence of organic matter in the soil greatly influences the ability of the soil to maintain soil fertility and productivity through the activity of soil microorganisms in improving the physical, chemical and biological properties of the soil [13]–[15]. Thus it can be said that soils with low organic matter content will reduce their buffering capacity against all chemical, physical and biological activities of the soil [16].

The development of smartphone technology is now starting to penetrate every aspect of modern life [17]. With such high levels of access and utilization, there is currently a lot of potential for the development of smartphones as high-performance tools in several countries industry [18]. Traditionally, smartphones have been used as an example of point-of-care testing devices in developing countries, now a similar approach could be extended to agriculture [19], [20]. Today, many organizations are using this technology to create smart objects. IoT plays an important role in the development of society at an advanced level [21], [22]. In this paper, we summarize IoT-based devices which are useful in agriculture and play a major role in helping users to know about crop cultivation.

Research [23], [24] stated that the increase in the number of application malware, the diversity in techniques, and the increase in damage. Therefore, it is very important to detect this software and improve user's mobile security. Static and dynamic analysis, behavior monitoring, machine learning methods are used to ensure security. In this study, the K-nearest neighbor (KNN) classifier, one of the machine learning methods, is used. Thus, it aims to detect malicious mobile software successfully and quickly. The KNN algorithm classifies by comparing unknown data points with similar training data points, measured by Euclidean distance [25]–[27] Attribute values are normalized to prevent attributes with a larger range from exceeding attributes with a smaller range [28]–[30].

For this research, researchers are trying to help in terms of checking the soil that will be planted with citrus fruits. In order for the land to be used optimally in planting citrus fruits, farmers must know the elements contained in the soil. Research applies the KNN method and utilizes a microcontroller for data input, by combining methods and microcontroller tools to assist the application process land [31], [32].

.

2. METHOD

2.1 Research Stages

In the research process, researchers carried out research stages with the first stage, namely data collection, designing input data, applying the KNN method, nutrient detection results, the research flow image is in Figure 1.

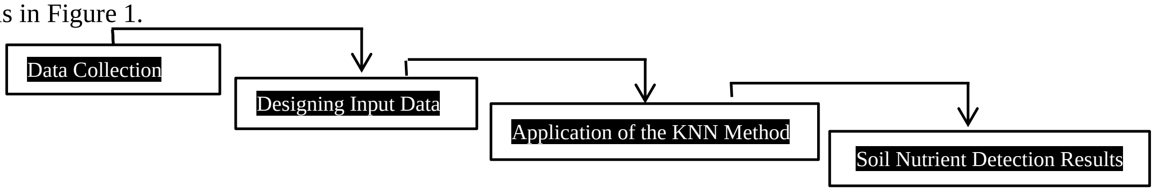

Figure 1. Research stages

2.2 Tools and Ways

In this study a tool is needed to check agricultural land in the form of soil. The resistance that is checked is in the form of elemental content found in the soil including nitrogen, calcium, phosphorus, pH and soil moisture [33]–[35]. So in this study to find out the contents of the elemental content in the soil an Android-based application will be made using a microcontroller. The tools needed to create research results are :

1) For Android applications, an Android smart phone is required

   Microcontroller tool as the detection of elements in the soil. The workings of the microcontroller are based on the modules in this tool which will later process the search for soil nutrients based on the instructions in the module. In the module there are instructions that instruct steps and flowcharts for collecting soil nutrient data including nitrogen, calcium, phosphorus, pH and soil moisture. From the data that has been taken using Bluetooth will be sent to the android application [36].

2) Bluetooth is used to send data in the form of a signal on the microcontroller device to the android application[37], [38].

   The method used in the series of system designs that will be created in this research is:

a) The first stage activates the existing application on Android.
b) Activate the function of the microcontroller tool.
c) After the tool and application are active, then plug the microcontroller into the soil to check the soil nutrient content.
d) Then the microcontroller device will send data via a Bluetooth signal to the Android application.
e) The application then processes the data to produce output in the form of information.
f) The information conveyed is in the form of resistant content elements that are checked.

2.3 Algorithm Design

In a system, of course there is a workflow that is carried out in it, on the microcontroller the workflow is according to the instructions in the module. The microcontroller workflow on the module can be described in a flowchart in Figure 2.

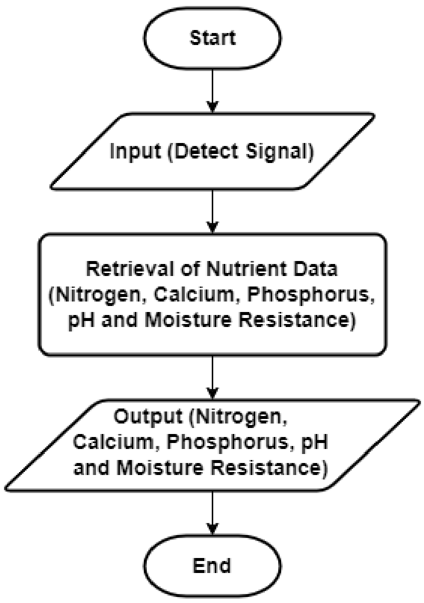

Figure 2. Microcontroller workflow

An input can be in the form of data input through an input device, in the form of a barcode or signal. In this study the input used was in the form of a signal using Bluetooth, while the Bluetooth workflow in this study can be described by flowchat Figure 3.

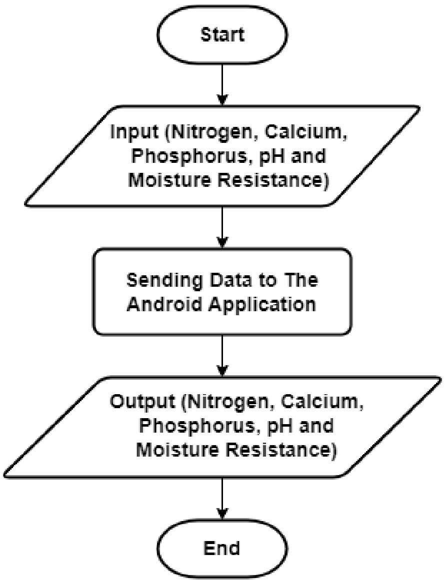

Figure 3. Bluetooth workflow

Before making an application, the process that must be carried out is to prepare the algorithm first so that the application to be made can provide the expected results in the form of the desired output [39]–[41]. The algorithm that we present is in the form of a flowchart because this presentation can be easily seen and understood. In this study, the algorithm design created is in Figure 4.

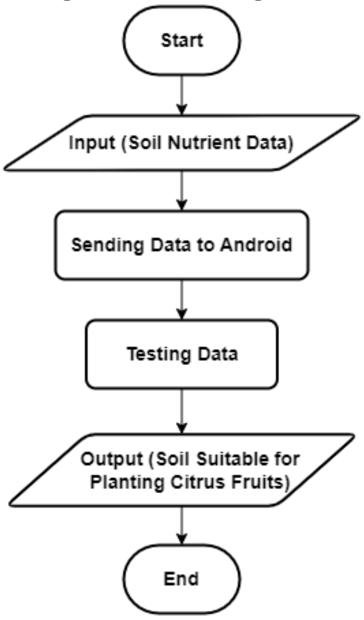

Figure 4. Algorithm workflow

2.4 KNN Calculation

In the table below is a sample data sheet which I think is in accordance with the content data for citrus plants, and in the data in Determining attribute weights and proximity values the researcher provides an explanation of the function of the determining attributes, and the function of the proximity value of the soil sensor. Before looking for the percentage of similarity in soil content, normalization is carried out on the 5 criteria for citrus fruit soil content used in calculations using the KNN method [42], [43]. For normalized values on the values of the elements nitrogen, calcium, phosphorus, PH and moisture resistance is done by dividing by 100 [44], [45]. Example:

1. Humidity Normalized Value = 81,92/100
   = 0,82
2. Normalized value of soil pH = 0,55
3. Nitrogen Normalized Value = 0,34
4. Phosphorus Normalized Value = 39,39/100
   = 0,39
5. Normalized Value of Potassium = 0,73

Table 1. Soil normalization values of citrus soil content

Soil Nutrients	Not yet Normalized		Normalized		Proximity Weight	Weight
	Database	Trials	Database	Trials		
Soil Moisture	78,92	81,92	0,79	0,82	0,97	1
Soil pH	4,58	5,51	0,46	0,55	0,91	1
Nitrogen	0,34	0,23	0,34	0,23	0,89	1
Phosphorus	39,39	24,29	0,39	0,24	0,85	1
Calcium	0,73	0,87	0,73	0,87	0,86	1

After the normalization process is carried out, the data in the master data and test data are carried out by the closeness process. Meanwhile, to find the percentage of closeness. For this study, the weight value was given a value of 1, the percentage calculation was carried out for 5 similarities in the soil content of citrus fruits in the datasheet. The example of the calculation in the trial of the first soil content in the datasheet and the calculation of the percentage of similarity with the KNN method. Calculation of the Proximity Percentage, namely (1 - (abs (datasheet - test data)) * 100%. Calculation results on trial data:

1. Percentage of Proximity of Moisture Value
   = (1 – (abs (0.79-0.82)) * 100 %)
   = 0.97 %
2. Percentage Calculation on K-NN
   = (1*0.97)+(1*0.91)+(1*0.89)+(1*0.85)+(1*0.86)] / 5
   = 4.48 / 5
   = 0.896
   = 89.6 %

2.5 Application Development Plan

In designing a software development system, a microcontroller device will be created that is used to retrieve soil nutrient data. This collection is done by plugging the tool into the soil, then the data collected includes the nutrients nitrogen, calcium, phosphorus, pH and soil moisture will be sent. By using a Bluetooth signal, the existing data will be sent to the Android application. In addition to making a microcontroller tool, this research also created an Android-based application to display data. This application will select existing data to produce information that will be presented to application users, namely citrus farmers and prospective citrus farmers. The information that will be conveyed from the android application is the nutrient content received from the microcontroller and whether this nutrient content is suitable for planting citrus fruits. The system design is in Figure 5.

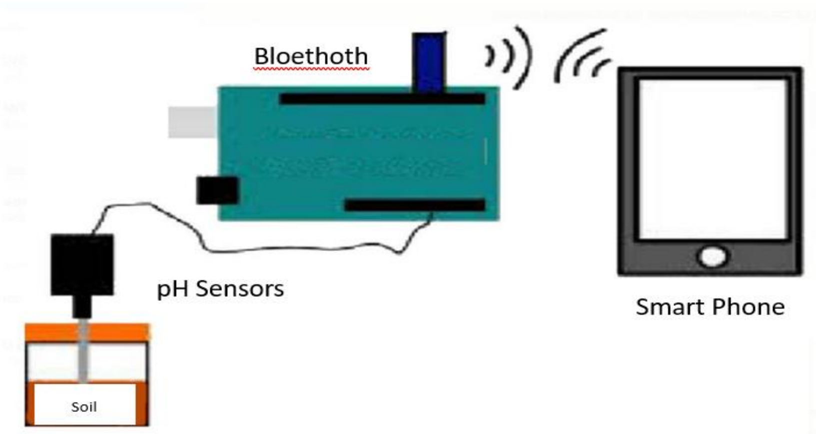

Figure 5. Application development design

3. RESULTS AND DISCUSSIONS

In this study a tool is needed to check an agricultural land in the form of soil. And the soil that is checked is in the form of elemental content found in the soil including nitrogen, calcium, phosphorus, pH and soil moisture. So in this study to find out the contents of the elemental content in the soil an Android-based application will be made using a microcontroller. The tools needed to create the results of this research are:

a. For Android applications, a smartphone is needed in the form of an Android with a minimum of 2GB RAM.
b. For the microcontroller tool as a detection of soil content elements, the series of data input devices that are made can later be seen in Figure 6.

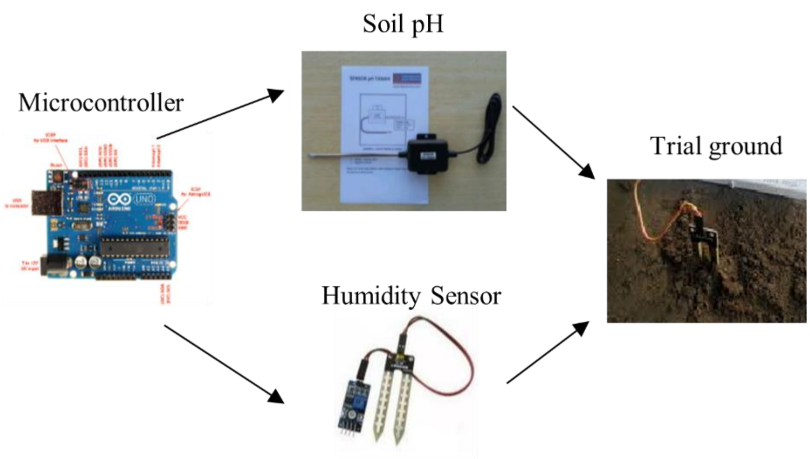

Figure 6. Series of data input devices

c. The workings of the microcontroller are based on the modules in the tool, which will process the search for soil nutrients based on the instructions in the module. In the module there are instructions that instruct steps and flowcharts for collecting soil nutrient data including nitrogen, calcium, phosphorus, pH and soil moisture. From the data that has been taken using Bluetooth will be sent to the android application.
d. Bluetooth is used to send data in the form of a signal that is on the microcontroller device into the android application.
e. The methods used in the series of system designs that will be created in this study are:
   1) The first stage opens an existing application on Android.

.

2) Turn on the microcontroller.
3) After the tool and application are active then connect the Bluetooth Tool to the Smartphone after it is connected then plug the sensor device into the soil which will be checked for soil nutrient content, Then the microcontroller device will send data via Bluetooth signal to the android application.

The next step is to prepare datasets for trials or testing, here the researcher uses a datasheet of 6 datasets as shown in table 2. The design of the index for implementing the KNN function in checking the suitability of soil nutrients in the dataset will consist of 6 datasets. In the table it is explained that the researcher uses an index to collect each data for soil nutrients, including elements of nitrogen, phosphorus, potassium, pH and soil moisture. If the value of the average index called is similar or close to the tested nitrogen, phosphorus, and calcium values, the classification application will display output according to the arrangement in the dataset.

Table 2. Design Index for the Implementation of KNN Functions

Nitrogen	Phosphorus	Calcium	pH	Humidity	Remarks
0,23	24,29	0,87	5,51	81.92%	Can
0,17	45,12	0,80	5,38	76.05%	Can
0,23	30,52	0,42	2,91	77.22%	Can
0,17	48,43	0,698	0.24	27,14%	Can't
0,2	47,25	0,658	-0.45	27,50%	Can't
0,34	39,39	0,729	-0.35	26.16%	Can't

In the early stages of testing, all data input devices were activated and connected to each other and in the application the microcontroller was connected to Bluetooth. pH and Humidity sensors are plugged into the soil which will detect soil nutrient compatibility. After everything is connected, the sensor values will appear as pH and humidity values, while nitrogen, phosphorus and potassium values will be input manually. After all the input data is filled in, click the import dataset button, then click the classification results button to see the results. From the results of research conducted in [28] using the KNN algorithm in the classification process, it shows a significant improvement with the right choice of k parameters, using appropriate distance metrics, combining attribute weighting and pruning data containing points. From the results of checking the suitability of soil nutrients, it produces information about the suitability of the trial data with the dataset whether the soil can be planted with citrus fruits or not. Figure 7 shows the results of the classification according to the datasheet, so the command "results of classification can be planted" appears in the output. If the variable value is different from the dataset, the command "cannot be planted" appears in the output classification.

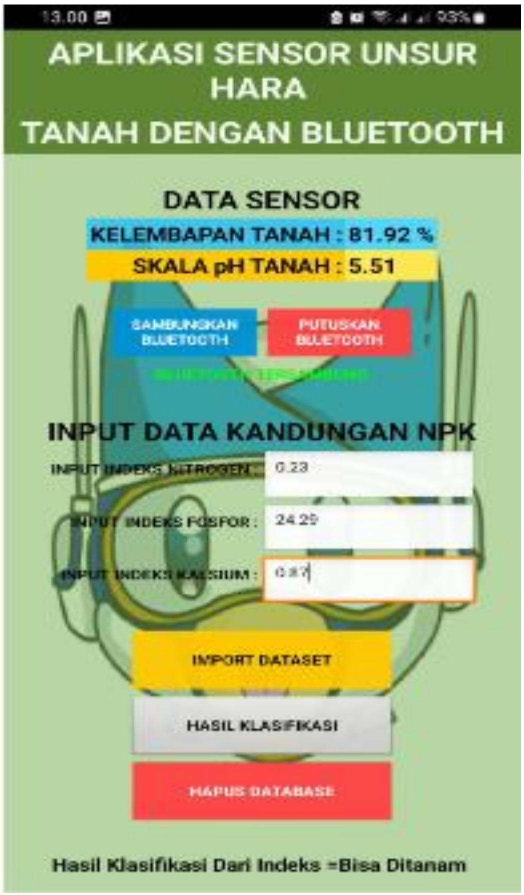

Figure 7. Display of soil nutrient compatibility applications

4. CONCLUSION

The results of the research that has been carried out produce an application to check soil nutrients by applying the KNN method and utilizing a microcontroller as an input device. The application of the KNN method to the soil nutrient check application can be produced with a suitability value of 89.6% through the trial stages produced with the existing dataset. With the Android-based soil nutrient compatibility application, it can help citrus fruit farmers to find out the nutrient content of the soil before planting citrus fruits. From the results of the research that has been carried out, researchers can conclude that the application of the KNN method can help in the process of detecting soil nutrients and the microcontroller tool can help with the automatic data input process. In future research developments, it is necessary to add automatic NPK input and apply new methods to increase the accuracy of detection results.

REFERENCES

[1] E. Amalia, “Analisis Rantai Pasok (Supply Chain) Kopi Robusta Di Dusun Gondang, Desa Darungan, Kecamtan Tanggul, Kabupaten Jember.” Institut Agama Islam Negeri Jember, 2020.

[2] U. N. Mufida Husna, “Pemetaan Tingkat Produktivitas Jeruk Siam (Citrus nobilis) dengan Sistem Pengolahan Mandiri di Kabupaten Banyuwangi.” Politeknik Negeri jember, 2023.

[3] J. C. Kilmanun, T. Purbiaty, and T. Sugiarti, “Pengembangan Kawasan Jeruk Berbasis Korporasi di Kabupaten Banyuwangi Jawa Timur The Development of Citrus Area With Coorporation Based in Banyuwangi East Java,” in *Prosiding Seminar Nasional*, 2020.

[4] K. D. Susila, “Studi Keharaan Tanaman dan Evaluasi Kesuburan Tanah di Lahan Pertanaman Jeruk Desa Cenggiling , Kecamatan Kuta Selatan,” vol. 3, no. 2, pp. 13–20, 2013.

[5] A. A. Wiguna and L. E. Widyatami, “Penerapan Sistem Tabulampot Pada Jenis Tanaman Mangga dan

.

Jeruk di Kelurahan Karangrejo Kecamatan Sumbersari Kabupaten Jember," *Semin. Has. Penelit. dan Pengabdi. Masy. Dana BOPTN Tahun 2016, ISBN 978-602-14917-3-7 Penerapan*, pp. 211–214, 2016.

[6] A. Chusyairi *et al.*, "Aplikasi E-Soil untuk Mengidentifikasi Warna Tanah Berbasis Android Menggunakan Munsell Soil Color Chart E-SOIL APPLICATION TO IDENTIFY SOIL COLORS BASED ON ANDROID USING THE MUNSELL SOIL COLOR CHART," *Maret 2019 IJCCS*, vol. 09, no. 01, pp. 1–5, 2019.

[7] R. S. ARSLAN and A. H. Yurttakal, "K-Nearest Neighbour Classifier Usage for Permission Based Malware Detection in Android," *Icontech Int. J.*, vol. 4, no. 2, pp. 15–27, 2020, doi: 10.46291/icontechvol4iss2pp15-27.

[8] H. Pratama, A. Yunan, and R. Arif Candra, "Design and Build a Soil Nutrient Measurement Tool for Citrus Plants Using NPK Soil Sensors Based on the Internet of Things," *Brill. Res. Artif. Intell.*, vol. 1, no. 2, pp. 67–74, 2021, doi: 10.47709/brilliance.v1i2.1300.

[9] R. Widowati, "Keberhasilan Okulasi Varietas Jeruk Manis Pada Berbagai Dosis Pupuk Majemuk Npk," *AgroSainT*, vol. 8, no. 1, pp. 56–61, 2017.

[10] S. Widyastuti, "Penerapan Konsep Kurikulum Hijau dan Kimia Hijau dalam Desain Praktikum dan Pengolahan Limbah Laboratorium Kimia," *Indones. Green Technol. J.*, vol. 11, no. 01, pp. 38–45, 2022, doi: 10.21776/ub.igtj.2022.011.01.03.

[11] V. Manivasan, "Soil & Water Compatibility Testing Based on IOT," pp. 332–334.

[12] F. S. Harahap, H. Walida, and I. Arman, *Dasar-dasar Agronomi Pertanian*. CV. Mitra Cendekia Media, 2021.

[13] N. Senesi and E. Loffredo, "The chemistry of soil organic matter," in *Soil physical chemistry*, CRC press, 2018, pp. 239–370.

[14] A. Kicińska, R. Pomykała, and M. Izquierdo-Diaz, "Changes in soil pH and mobility of heavy metals in contaminated soils," *Eur. J. Soil Sci.*, vol. 73, no. 1, p. e13203, 2022.

[15] W. J. Werner, J. Sanderman, and J. M. Melillo, "Decreased soil organic matter in a long-term soil warming experiment lowers soil water holding capacity and affects soil thermal and hydrological buffering," *J. Geophys. Res. Biogeosciences*, vol. 125, no. 4, p. e2019JG005158, 2020.

[16] H. Dvořáčková, J. Dvořáček, P. Hueso González, and V. Vlček, "Effect of different soil amendments on soil buffering capacity," *PLoS One*, vol. 17, no. 2, p. e0263456, 2022.

[17] A. Colbert, N. Yee, and G. George, "The digital workforce and the workplace of the future," *Academy of management journal*, vol. 59, no. 3. Academy of Management Briarcliff Manor, NY, pp. 731–739, 2016.

[18] D. Reed, D. Gannon, and J. Dongarra, "Reinventing high performance computing: challenges and opportunities," *arXiv Prepr. arXiv2203.02544*, 2022.

[19] K. Golicz, S. Hallett, R. Sakrabani, and J. Ghosh, "Adapting smartphone app used in water testing, for soil nutrient analysis," *Comput. Electron. Agric.*, vol. 175, no. October 2019, p. 105532, 2020, doi: 10.1016/j.compag.2020.105532.

[20] E. C. Hobbs, A. Colling, R. B. Gurung, and J. Allen, "The potential of diagnostic point-of-care tests (POCTs) for infectious and zoonotic animal diseases in developing countries: Technical, regulatory and sociocultural considerations," *Transbound. Emerg. Dis.*, vol. 68, no. 4, pp. 1835–1849, 2021.

[21] G. B. Raja, "Impact of internet of things, artificial intelligence, and blockchain technology in Industry 4.0," *Internet Things, Artif. Intell. Blockchain Technol.*, pp. 157–178, 2021.

[22] S. Kumar, P. Tiwari, and M. Zymbler, "Internet of Things is a revolutionary approach for future technology enhancement: a review," *J. Big data*, vol. 6, no. 1, pp. 1–21, 2019.

[23] E. Z. Ferdousy, M. M. Islam, and M. A. Matin, "Combination of Naïve Bayes Classifier and K-Nearest Neighbor (cNK) in the Classification Based Predictive Models," *Comput. Inf. Sci.*, vol. 6, no. 3, 2013, doi: 10.5539/cis.v6n3p48.

[24] R. Pambudi and F. Madani, "Analysis of public opinion sentiment against COVID-19 in Indonesia on twitter using the k-nearest neighbor algorithm and decision tree," *J. Soft Comput. Explor.*, vol. 3, no. 2, pp. 117–122, Sep. 2022, doi: 10.52465/joscex.v3i2.88.

[25] K. Taunk, S. De, S. Verma, and A. Swetapadma, "A brief review of nearest neighbor algorithm for learning and classification," in *2019 international conference on intelligent computing and control systems (ICCS)*, IEEE, 2019, pp. 1255–1260.

[26] O. Adepoju, J. Wosowei, and H. Jaiman, "Comparative evaluation of credit card fraud detection using machine learning techniques," in *2019 Global Conference for Advancement in Technology (GCAT)*, IEEE, 2019, pp. 1–6.

[27] A. Nurdina and A. B. I. Puspita, "Naive Bayes and KNN for Airline Passenger Satisfaction Classification: Comparative Analysis," *J. Inf. Syst. Explor. Res.*, vol. 1, no. 2, pp. 83–92, 2023, doi: https://doi.org/10.52465/joiser.v1i2.167.

[28] S. Hota and S. Pathak, “KNN classifier based approach for multi-class sentiment analysis of twitter data,” *Int. J. Eng. Technol.*, vol. 7, no. 3, pp. 1372–1375, 2018, doi: 10.14419/ijet.v7i3.12656.

[29] S. Nayak, M. Bhat, N. V. S. Reddy, and B. A. Rao, “Study of distance metrics on k - Nearest neighbor algorithm for star categorization,” *J. Phys. Conf. Ser.*, vol. 2161, no. 1, 2022, doi: 10.1088/1742-6596/2161/1/012004.

[30] Y. Yao, L. Zheng, X. Yang, M. Naphade, and T. Gedeon, “Simulating content consistent vehicle datasets with attribute descent,” in *Computer Vision–ECCV 2020: 16th European Conference, Glasgow, UK, August 23–28, 2020, Proceedings, Part VI 16*, Springer, 2020, pp. 775–791.

[31] M. A. Imron and B. Prasetiyo, “Improving Algorithm Accuracy K-Nearest Neighbor Using Z-Score Normalization and Particle Swarm Optimization to Predict Customer Churn,” *J. Soft Comput. Explor.*, vol. 1, no. 1, pp. 56–62, 2020, doi: 10.52465/joscex.v1i1.7.

[32] A. Fitriandi, E. Komalasari, H. G.-J. R. dan, and undefined 2016, “Rancang Bangun Alat Monitoring Arus dan Tegangan Berbasis Mikrokontroler dengan SMS Gateway,” *Academia.Edu*, vol. 10, no. 2, 2016.

[33] L. Burton, K. Jayachandran, and S. Bhansali, “Review—The ‘Real-Time’ Revolution for In situ Soil Nutrient Sensing,” *J. Electrochem. Soc.*, vol. 167, no. 3, p. 037569, 2020, doi: 10.1149/1945-7111/ab6f5d.

[34] A. Lisowska, B. Filipek-Mazur, A. Kalisz, O. Gorczyca, and A. Kowalczyk, “Changes in Soil Sulfate Sulfur Content as an Effect of Fertilizer Granules Containing Elemental Sulfur, Halloysite and Phosphate Rock,” *Agronomy*, vol. 13, no. 5, p. 1410, 2023.

[35] L. Grimond, D. Rivest, S. Bilodeau-Gauthier, R. Khlifa, R. Elferjani, and N. Bélanger, “Novel soil reconstruction leads to successful afforestation of a former asbestos mine in southern Quebec, Canada,” *New For.*, pp. 1–27, 2023.

[36] A. D. B. Sadewo, E. R. Widasari, and A. Muttaqin, “Perancangan Pengendali Rumah menggunakan Smartphone Android dengan Konektivitas Bluetooth,” *J. Pengemb. Teknol. Inf. dan Ilmu Komput.*, vol. 1, no. 5, pp. 415–425, 2017.

[37] M. Santo Gitakarma and T. K. Priyambodo, “A real-time smart home system using android Bluetooth control device module,” in *2019 International Symposium on Electronics and Smart Devices (ISESD)*, IEEE, 2019, pp. 1–7.

[38] U. A. Ramadhani, I. D. G. H. Wisana, and P. C. Nugraha, “Smartphone based respiratory signal monitoring and apnea detection via bluetooth comunication,” *J. Teknokes*, vol. 14, no. 2, pp. 49–55, 2021.

[39] J. Andi, “Pembangunan Aplikasi Child Tracker Berbasis Assisted – Global Positioning System (A-GPS) Dengan Platform Android,” *J. Ilm. Komput. dan Inform.*, vol. 1, no. 1, pp. 1–8, 2015.

[40] S. Postolache, P. Sebastião, V. Viegas, O. Postolache, and F. Cercas, “IoT-Based Systems for Soil Nutrients Assessment in Horticulture,” *Sensors*, vol. 23, no. 1, 2023, doi: 10.3390/s23010403.

[41] T. Toyao, Z. Maeno, S. Takakusagi, T. Kamachi, I. Takigawa, and K. Shimizu, “Machine learning for catalysis informatics: recent applications and prospects,” *Acs Catal.*, vol. 10, no. 3, pp. 2260–2297, 2019.

[42] H. S. El Imanni *et al.*, “Multispectral UAV data for detection of weeds in a citrus farm using machine learning and Google Earth Engine: Case study of Morocco,” *Remote Sens. Appl. Soc. Environ.*, vol. 30, p. 100941, 2023.

[43] C. Dewi and Y. K. Arbawa, “Performance evaluation of distance function in KNN and WKNN for classification of soil organic matter,” in *2019 International Conference on Sustainable Information Engineering and Technology (SIET)*, IEEE, 2019, pp. 196–199.

[44] A. Erler, D. Riebe, T. Beitz, H. G. Löhmannsröben, and R. Gebbers, “Soil nutrient detection for precision agriculture using handheld laser-induced breakdown spectroscopy (LIBS) and multivariate regression methods (PLSR, lasso and GPR),” *Sensors (Switzerland)*, vol. 20, no. 2, 2020, doi: 10.3390/s20020418.

[45] R. Madhumathi, T. Arumuganathan, and R. Shruthi, “Soil Nutrient Detection and Recommendation Using IoT and Fuzzy Logic,” *Comput. Syst. Sci. Eng.*, vol. 43, no. 2, pp. 455–469, 2022, doi: 10.32604/csse.2022.023792.

.