ESP IJSHMS
ESP International Journal of Science, Humanities and Management Studies
ISSN: 2583-9756 / Volume 1 Issue 1 July 2023 / Page No: 1-8
Paper Id: IJSHMS-V1I1P101 / Doi: 10.56472/25839756/IJSHMS-V1I1P101

Original Article

Review of Electronic Methods of Soil Nutrient Testing for Indian Crops

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Received Date: 10 June 2023 Revised Date: 18 June 2023 Accepted Date: 01 July 2023

Abstract**:** *Farming is the main occupation in India and the climate of a particular place becomes an important factor. Also every region has a different type of soil. The Quality of soil decides the type of crop that is a best fit for it. But soil lacks many important nutrients at some places so though there is land, still no plantation can take place. So one needs to not only keep a check on parameters like pH & moisture content of soil but also overall temperature and humidity of the place. Till date, individuals are taking above measurements manually and also keeping a periodic check on them. In India, from every state around 9 to 10 lakhs of soil samples are sent for testing in laboratories located in the vicinity. But often due to abundance of soil samples and less number of soil testing labs with very limited man power, the farmers have to wait long to get crop recommendations for their field. Plus the farmers now-a-days take 2 to 3 different type of crops in a year. So they need to have proper knowledge and guidance related to the above in addition to which fertilizers are required to be sprayed for supplying additional nutrients in order to get maximum yield. This paper presents a review of the different approaches of soil nutrient testing while deciding the flow of work to be done in developing an integrated electronic system to analyze soil nutrients.*

Keywords: *Soil Nutrients, Traditional Approaches, Micro Nutrients, Macro Nutrients.*

I. INTRODUCTION

India is an agricultural country. Since in India, farming is the main occupation ,so the quality of soil, its viability becomes a very important parameter while deciding the crops that would give a lot of yield. Till date soil testing is done by exposing it to chemicals.

Soil Testing is thus an essential process that needs to be carried out to know the attributes of soil and get an idea about type of fertilizers required to overcome the inherent deficiency of nutrients present in any soil sample. Soil testing process is thus a scientific process. Soil testing began in India in 1955 by setting up 16 soil testing laboratories. Now the count has increased a lot. Government of India too lends a whole hearted support to this initiative. But no full proof electronic system is made for this till date. Even now, the soil sample is taken by farmers to soil testing labs where it is exposed to chemicals to test its nutrients. This process is very time consuming and may be error prone. Also the results obtained may vary according to climatic conditions too. In total there are 12 parameters that have to be specifically looked after viz pH, Salinity, Organic Carbon, Nitrogen, Phosphorous, Potassium, Sulphur, Zinc, Boron, Iron, Manganese & Copper. The composition and appropriate percentage of these parameters is required to have a high yield . The climatic conditions also contribute a lot to the selection of crop in a particular place. If the soil at a particular place lacks the required nutrients , they can be additionally supplied through fertilizers . But to have a analysis of all of this a very precise soil test is a must. No full proof electronic system is made for design & Analysis of soil nutrients. During the course of my research work, an integrated electronic system would be designed to analyse the soil nutrients, its overall viability and suggest which crop is the best fit for which type of soil. However, prior to that a detailed analysis of existing systems and different approaches used till date has to be carried out. This research paper highlights above 2 aspects.

II. TRADITIONAL METHODS OF SOIL TEST

Soil testing is often performed by commercial local labs that that test the soil sample by exposing it to different chemicals. The advantage is that the man power employed in these local labs is aware about attributes of soil taken from the

nearby area and so they perform precise chemical tests. Based upon the result, the technicians then recommend appropriate fertilizers to overcome deficiency of nutrients in the soil.

Traditional methods of soil tests include exposing the soil to various chemical tests. There are 3 categories of plant nutrients :

1. Major nutrients: nitrogen (N), phosphorus (P), and potassium (K)
2. Secondary nutrients: sulfur, calcium, magnesium
3. Minor nutrients: iron, manganese, copper, zinc, boron, molybdenum, chlorine, etc.
4. For instance, the amount of phosphorous available in soil is mostly measured by chemical extraction method. Different countries follow different standard methods. Based on soil testing results, the composition and dosage of fertilizer for the specific land is recommended for both agricultural and horticultural industries.
5. Devices used in National Soil Testing Lab for measuring different parameters are as under

Figure 1: Soil Testing by Traditional Methods

A. Atomic Absorption Spectrometer :

This device is used to identify & quantify soil micronutrients /heavy metals like manganese, copper, iron, zinc, lead, etc. here 1 gm soil is mixed with various solutions (mostly acids) & then exposed to the meter. The result on the screen displays the name and amount of micronutrients present in the test soil sample

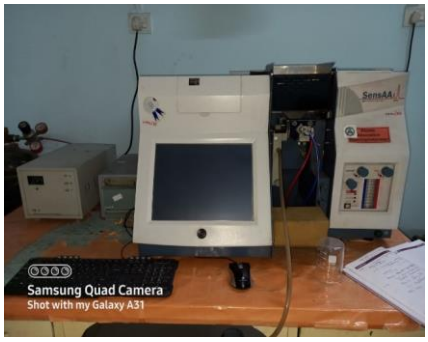

Figure 2: Atomic Absorption Spectrometer

B. UV Spectrometer:

This device uses the calorimetric technique to determine phosphorous, sulphur , boron.

Figure 3: UV Spectrometer

C. Flame Photometer

This device is used to determine amount of potassium, calcium, sodium, lithium

Figure 4: Flame Photometer

D. Other analysers

Figure 5: Nitrogen Analyser

Figure 6: Oxygen Analyser

E. The soil Health Card initiative of Government of India

Soil Health Card Scheme is launched by the Government of India on 19 February 2015. Under the scheme, the government issues soil health cards to farmers. These cards give information about the nutrients present in a particular type of soil based on test results performed by chemical exposure to soil samples and then the experts recommend supply of additional nutrients through fertilisers required for the individual farms thus helping farmers to improve productivity. The result and suggestion will be displayed on the cards. Thus, the Soil Health Card would provide every farmer soil nutrient status of his land and advice him accordingly on the dosage of fertilizers and essential soil amendments to be made for good soil health. Soil Health Card Scheme is thus very helpful for the farmers of the country.

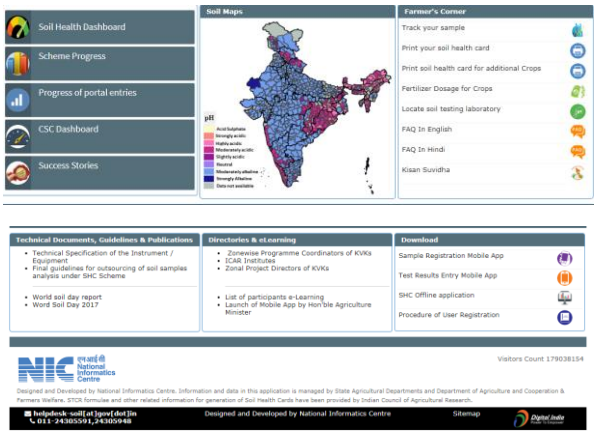

Figure 7: Soil Health Card dashboard

Then, upon clicking on the soil health dashboard, one needs to select state, district, sub district, village so as to get an idea about the soil quality & nutrient contents in it. All the results published on the dashboard are obtained after doing chemical treatments on the soil.

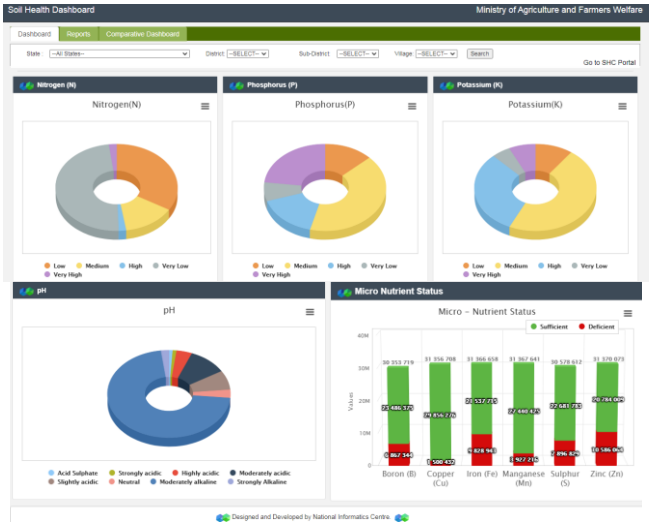

Figure 8: Pictorial representation of soil nutrients on Soil Health Card dashboard

III. REVIEW OF LITERATURE RELATED TO SOIL TEST

One of the approaches to identify nutrients present in soil and determine soil pH is through image processing and artificial neural network. . For this Soil Test Kit [1] (STK) is used. The method is called Rapid Soil Testing (RST) and is recommended by the Bureau of Soils and Water Management. The parameters like (1) pH, (2) Nitrogen, (3) Phosphorus, (4) Potassium, (5) Zinc, (6) Calcium, and (7) Magnesium can be determined by this method. There are 5 phases in the composition of the system viz soil testing, image capturing, image processing, training system for neural network and result. Artificial Neural Network is used to sped up the performance of image processing phase so as to get precise result. The entire system is base3d up upon the captured images. Out of the data extracted from the captured images 70% is utilised for training, 15% for testing and the remaining 15% for validation of outputs obtained. Neural network toolbox of MATLAB is used for this. The quality of soil, amount of nutrients in it and the pH are displayed as results. The results were found to be accurate when compared with other traditional methods. Also a mobile app can be developed to display these results. OpenCV library can also be alternatively used for the image processing phase while a tool called Eclipse can be used for Android development stage[34].

Yet another way of analyzing pH and presence of nutrients like nitrogen, phosphorous & potassium is by developing a device that can use colorimetry technique. Here recommendation of deficient nutrients can be given through the use of chemicals available in the Soil Test Kit [2]. In this method, color references were considered by doing color reaction trials of various reactants. Then using TCS3471 color sensor and LDR color sensor the RGB values were extracted. For testing nutrients present in soil 3 samples were taken for each wheras for testing pH level of soil 10 trials were done. 0.05 values were chosen as benchmark to get precise results. Finally, there was a comparison done between the value of pH & other soil

nutrients computed by this method with the traditional manual methods. It was observed that values obtained by both the methods were almost same.

In order to estimate soil moisture content, a fringing field capacitive moisture sensor was also fabricated and implemented through PCB technology [3]. Then its performance evaluation was carried out using 4 different soil samples taken for 4 different farms located far away from each other. The results obtained were compared with the standard gravimetric method to estimate moisture content in the soil.

In order to investigate environmental conditions, wireless Sensor Networks can be utilised. This in turn can be carried out using a set of spatially distributed sensors. by cooperatively exchanging data between nodes till the Gateway node is reached. [19]. Soil parameters like temperature & humidity can also be measured using wireless sensor networks [4]. For this special sensors were designed that could be placed underground to get precise readings. Using the soil measurements collected by them a network was created. The network was created using low power autonomous nodes. Further using Internet of things and cloud service communication protocol spatial distribution maps of soil parameters at two different levels below ground was generated [6]. Probabilistic Communication protocol was applied to the proposed hierarchical wireless sensor network so as to get low duty cycle thereby ensuring an appreciable life time for soil monitoring applications. The measured values of the soil parameters taken from underground electrodes were then delivered to the nodes above the ground. The nodes above ground level are referred to as relay nodes. The underground nodes used their radios to transmit values to relay nodes. From here then the data is forwarded to to base nodes by those relays that are capable of long range communication. The base node is ultimately connected to the workstation. In this way the workstation gets value of the various soil parameters. Not only temperature and humidity, other soil nutrients like nitrogen, phosphorous, potassium could also be measured & their data too could be put on cloud [37]. Thus by using sensor network technology the farmers are able to have a better understanding about the soil on which they will cultivate, its qualities, its deficiencies, etc. This in turn helps the farmers to decide the type of crop they wish to harvest and the preventive steps to be taken at appropriate time to avail maximum yield. This ensures time saving, labour saving, money saving and making optimum use of available resources[28] since all the values related to all the mentioned components get displayed on their mobile phone [14]

For measuring nitogen, phosphorous & potassium content in soil, a detection system based on optical sensor i.e an optical transducer is developed [16] [17]. The system essentially comprises of two LEDs acting as light sources with a photodiode as a detector. A signal conditioning circuit is also included. The complete assembly is placed in a transparent container made of PET (Polyethylene Terephthalate) [16]. The electrodes of the optical transducer thus designed are placed in the soil under test. The Nitrogen, Phosphorous & Potassium content present in the soil sample is estimated by amount of light absorbed by each nutrient. [17]. These are also referred to as Color Sensors & can very aptly measure the NPK values in a given soil sample [5].

Several articles related to case studies for determining soil nutrients are also cited. To decide the cropping sequence of rice and wheat in a farm, a slightly different approach was tried out in California [7]. Wet oxidation method was used for determining organic carbon in soil wheras soil nitrogen, potassium and phosphorous were determined by exposing the soil sample to various chemical tests. From the tests carried out it was studied how soil potassium (K) balances affect soil K indices. Also which is the best soil test indicator of plant K was investigated along with it's availability and the relationship between plant and soil K indices [9]. Similarly, in Haryana, India many Field Based Investigations were carried out. With the help of Satellite Image Processing, the Vegetation Index for Rice was estimated. After the case study, it was suggested that in order to improve the rate of crop productivity, diversified triple based alternative cropping systems can be very effectively utilised resulting in increase in net return income in this area [11]. In South Kashmir, India too soil samples from 3 sites were randomly selected and it was observed that there was a wide distribution of nutrients because of its complex land use . soil texture variations and organic carbon content was found to be high. Available macronutrient (N, P, K and S) and the DTPA-extractable nutrient (Zn, Cu, Mn and Fe) content in soils were medium to high in range in all the pasture lands of south Kashmir [12].

Last but not the least, Machine Learning approach can also be used to estimate the nutrients present in soil. To find amount of deficiency of the nutrients in the soil, linear regression algorithm can be used. From the results obtained after applying this algorithm the farmers will get to know the type of plants that are best suited for their field [38]. The farmers then plant crops in their fields accordingly. They follow the instructions given by the experts for the type and dosage of fertiliser which is made available to them at an affordable cost. This method is also referred to as prepared capsule technique for detection of soil nutrients. Results obtained about the content of N,P,K can be compared with the color chart. Then system will check the amount of the N, P, K in the soil and if deficiency is found, then the system itself will dispense the required amount of nutrient[20]. Also Machine Learning Algorithms like K-Nearest Neighbours Algorithm, K-means Clustering can be

deployed and development of API (Application Programming Interface)can be done to analyse the soil nutrients and even a bot can be made to predict the level of nutrients to be added for higher yield[39].

IV. PROPOSED METHODOLOGY

After extensive literature survey, a methodological approach for designing an integrated electronic system that would analyse the soil nutrients, its overall viability and would also suggest which crop is the best fit for which type of soil by checking the attributes of the soil would be as under:

- To design an electronic system for analysing soil attributes, the required database for designing such a system would be taken from soil testing institute.
- A random soil sample from 4-8 corners of field would be taken
- An advanced system integrating different type of sensors & other required processors/ controllers will be designed.
- The soil under test will be placed in the system and will be analysed.

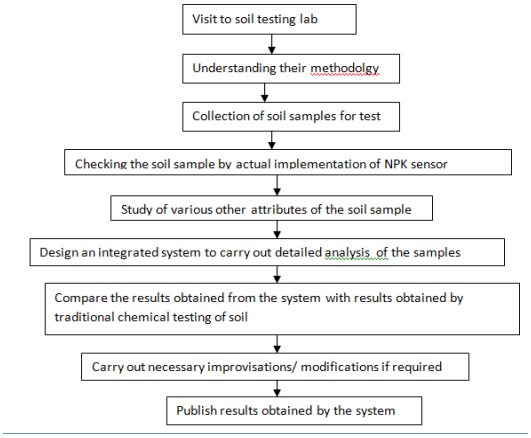

Figure 9: Flowchart showing overall procedure of soil testing

Table 1: Soil Health Card Data for Nagpur District

Health Card Data

District	Nagpur-Narkhed	Nagpur-Narkhed	Nagpur-Narkhed	Nagpur-Narkhed	Nagpur-Narkhed	Nagpur-Narkhed	Nagpur-Narkhed	Nagpur-Narkhed	Nagpur-Narkhed	Nagpur-Narkhed	Nagpur-Narkhed
Village	Agra	Ambada	Ambala	Arambhi	Babulkheda	Banor	Baradpavni	Belona	Bhaiwadi	Bharsingi	Dewali
pH	6.8	8.35	7.87	7.66	7.76	7	7.37	7.99	8.46	0.56	7.81
Salinity / Electrical Conductivity	0.3	0.37	0.25	0.35	0.23	0.28	0.36	0.37	0.23	0.57	0.29
Organic Carbon	0.62	0.12	0.73	0.42	0.77	0.23	0.83	0.42	0.25	45.26	0.57
Nitrogen	431.78	84.41	470.15	294	539.45	159.28	577.98	294.2	176.8	375	401.27
Phosphor	86.18	22.24	35.39	53.09	22.31	250.61	45.4	165.73	24.62	45.89	284.97
Potassium	441.37	305	1048.05	598.89	499.97	707.21	1253.68	558.03	419.7	47.56	519.59
Sulphur	9.9	--	0.27	7.2	6.7	9.7	9.1	8.2	1.3	12.45	7.6
Zink	0.29	1.97	0.42	0.38	0.28	0.39	0.68	0.3	0.48	32.56	0.23
Boron	0.15	1.09	0.94	0.09	0.08	1.35	0.17	1.71	0.19	45.28	1.41
Iron	2.91	19.94	1.26	3.95	1.1	2.82	0.48	1.26	1.29	47.56	1.39
Manganese	5.87	44.99	0.9	6.99	2.66	5.83	7.09	7.39	7.87	85.52	4.98
Copper	0.69	7.41	0.88	0.55	1.03	0.81	0.56	0.79	1.19	45.96	0.61
Crop1	Wheat	Cotton	Paddy(Dhaa	Wheat	Wheat	Paddy(Dhaa	Paddy(Dhaa	Tomato	Jowar(Sorg	Paddy(Dhaa	Paddy(Dhaa
Crop2	Arhar		Wheat	Paddy(Dhaa	Arhar	Wheat	Wheat	Wheat	Cucumbar		Wheat
Crop3	Paddy(Dhaa		Arhar	Bengal Gram	Paddy(Dhaa	Arhar	Soyabean	Arhar	Black Gram		Arhar
Crop4	Soyabean		Soyabean	Soyabean	Soyabean	Soyabean	Arhar	Soyabean	Horses Gra		Soyabean

V. EXPECTED OUTCOME

The proposed system when designed would aptly analyze the quality of soil presented to it & give a detailed analysis related to

- The overall quality of soil,
- The nutrients in it,
- Its viability and
- It would also suggest the best suited crop to produce a maximum yield.

The results would be compared with those obtained by traditional methods

VI. ACKNOWLEDGMENT

Dr. W.P Badole, Associate Professor, Soil Science and Agriculture Chemistry Section, National Soil Testing Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Nagpur, India

VII. REFERENCES

[1] "Determination of soil nutrients and pH level using image processing and artificial neural network", John carlo Puno, Edwin Sybinco, Elmer Dadios, Ira Vanenzeula,Joel Cuello, 2017 IEEE 9th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM), Philippines, Manila

[2] "Soil pH and nutrient (Nitrogen, Phosphorus and Potassium) analyzer using colorimetry", Rigor G Regalado, JeniferC Dela Cruz, 2016 IEEE Region 10 Conference (TENCON), Singapore

[3] "Design and Characterization of a Fringing Field Capacitive Soil Moisture Sensor", Manish Protim Goswami, Babak Montazar, Utpal Sarma, IEEE Transactions on Instrumentation and Measurement (Volume: 68, Issue: 3, March 2019)

[4] "A Novel Soil Measuring Wireless Sensor Network", Q.Wang, A.Terzisand A.Szalay, IEEE transactions on Instrumentation & measurement, August 2010

[5] "Design of Soil Nutrient System for Indian Crops", Dinesh B. Bhoyar, Sachin S.Khade, Swati.K. Mohod, S.Y.Ambatkar, International Journal of Future Generation Communication and Networking Vol. 13, No. 1, (2020), pp. 1446-1452

[6] "Smart Soil Parameters Estimation System Using an Autonomous Wireless Sensor Network With Dynamic Power Management Strategy", IEEE SENSORS JOURNAL, VOL. 18, NO. 21, NOVEMBER 1, 2018, Johan J. Estrada-López , Alejandro A. Castillo-Atoche, Javier Vázquez-Castillo , Edgar Sánchez-Sinencio,

[7] "Evaluation of Soil Test Methods for Available Nitrogen, Phosphorus and Potassium in Direct-Seeded Rice–Wheat Cropping Sequence", Journal of AgriSearch, ISSN : 2348-8808 (Print), 2348-8867 (Online) , Vijay Kant Singh , Poonam Gautam , Kharag Singh , Suman Sen , Vineet Kumar , Shiv Singh Meena and D.N.Singh

[8] "Soil Health in Cropping Systems: An Overview" Subhadip Paul, Neha Chatterjee, J. S. Bohra, S. P. Singh, D. Dutta, Rajesh Kumar Singh, and Amitava Rakshit, © Springer Nature Journal Singapore Pte Ltd. 2019 45 M. Hasanuzzaman (ed.), Agronomic Crops, https://doi.org/10.1007/978-981-32-9151-5

[9] Article on – "Assessment of potassium soil balances and availability in high yielding rice systems", Bruce A. Linquist • Johnny C. Campbell • published on 11th march 2022 in Springer Nature journal

[10] Article- " Multi-Channel Optoelectronic Measurement System for Soil Nutrients Analysis" Liuzheng Ma , Zhenfeng Li , Zephania Birech , Shixin Li ,Yatao Yang ,Wei Zhang 1 and Jiandong Hu ,published in MDPI electronics journal on 20 April 2019

[11] "Rice Equivalent Crop Yield Assessment Using MODIS Sensors' Based MOD13A1-NDVI Data" Vandana Tomar, Vinay Prasad Mandal, Pragati Srivastava, Shashikanta Patairiya, Kartar Singh, Natesan Ravisankar, Natraj Subash, and Pavan Kumar, IEEE SENSORS JOURNAL, VOL. 14, NO. 10, OCTOBER 2014

[12] Article-"Spatial distribution of soil nutrients in high altitude alpine pastures of south Kashmir Himalaya, India", published in March 2022 -Range Management and Agroforestry journal, J. A. Mugloo, Mehraj Khanday, Mehraj Dar*, Nazir A. Pala, Khursheed Ahmad and Javid Bhat

[13] "Design and Implementation of Soil Nutrient Monitoring System Based on "3S" Technology" ,Di Zu, Zhongbin Su , Xiaodong Yang, Xiaohe Gu,and Yancang Wang, International Journal of Smart Home Vol. 9, No. 5 (2015)

[14] "Soil NPK and Moisture analysis using Wireless Sensor Networks", Madhumathi R, Arumuganathan T, Shruthi R,11th IEEE international conference ICCCNT 2020 July 1-3, 2020 - IIT – Kharagpur

[15] "IoT based Classification Techniques for Soil Content Analysis and Crop Yield Prediction", R. Reshma, V. Sathiyavathi, T. Sindhu , K. Selvakumar, L. SaiRamesh, Fourth International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC)-2020

[16] "Integrated optical sensor for NPK Nutrient of Soil detection" Marianah Masrie*, Ahmad Zahid Mohd Rosli, Rosidah Sam, Zuriati Janin and Mohd Khairi Nordin, 2018 IEEE 5th International Conference on Smart Instrumentation, Measurement and Applications (ICSIMA 2018) 28-30 November 2018, Songkhla, Thailand

[17] "Detection of Nitrogen, Phosphorus, and Potassium (NPK) nutrients of soil using Optical Transducer" Marianah Masrie* , Mohamad Syamim Aizuddin Rosman, Rosidah Sam and Zuriati Janin, 4th IEEE International Conference on Smart Instrumentation, Measurement and Applications (ICSIMA) 28-30 November 2017, Putrajaya, Malaysia

[18] "Characterization of soil quality indicators: a study", M. Loganathan and Jothi Narendiran. N., Journal of Global Biosciences, ISSN 2320-1355, Vol. 3(2), 2014, pp. 586-592, http://mutagens.co.in, Date of Online: 28, April- 2014

[19] "Soil Quality Management using Wireless Sensor Network", Madhura U K, Akshay P, Akshay J Bhattad, Nagaraja G S , 2nd IEEE International Conference on Computational Systems and Information Technology for Sustainable Solutions 2017

[20] "An Automated Agricultural Robot" Leenata Vedpathak, Pooja Salape,, Snehal Naik, International Journal of Advanced Research in Computer and Communication Engineering Vol. 4, Issue 3, March 2015

[21] "IOT Based Smart Agriculture And Soil Nutrient Detection System", Akshay Badhe, Sandeep Kharadkar, Rushikesh Ware, Pratik Kamble, Prof. Shilpa Chavan,International Journal on Future Revolution in Computer Science & Communication Engineering ISSN: 2454-4248,Volume: 4 Issue: 4

[22] "Automated Soil Macro-Nutrient Analyzer Using Embedded Systems".,Harshal M. Khairnar; Sangeeta S. Kulkarni in 2018 Fourth International Conference on Computing Communication Control and Automation (ICCUBEA),Pune, India

[23] "Detection of N, P, K fertilizers in agricultural soil with NIR laser absorption technique", Arpit Rawankar; Mayurkumar Nanda; Hemant Jadhav; Prem Lotekar; Rahul Pawar; Libin Sibichan; Akshay Pangare, 3rd International Conference on Microwave and Photonics (ICMAP),9-11 Feb. 2018, Dhanbad , India

[24] "Automatic soil nutrients and crop detection management system using iot", Sonal S Udapudi ,Sonika R , Aravind E M, Prasad Shivam,Anoop G L, international journal of Advanced Research & innovative ideas in Education, IJARIIE, Vol-7 Issue-3 2021

[25] "A sensor device for measuring soil macronutrient proportion using FPGA", Vaibhav Ingale; Rashmi Vaidya; Amol Phad; Pratibha Shingare, 2016 International Conference on Communication and Signal Processing (ICCSP)

[26] "Soil moisture and atmosphere Components detection system using IOT and Machine Learning", Second International Conference on Smart Systems and Inventive Technology (ICSSIT 2019), Rishika Anand; Dimple Sethi; Kavita Sharma; Pooja Gambhir

[27] "IoT Based Farming Recommendation System Using Soil Nutrient and Environmental Condition Detection", Arun Kumar, Abhishek Kumar, Akash De, Shashank Shekhar, Rohan Kumar Singh , International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8 Issue-11, September 2019

[28] "Nutrients Detection in the Soil: Review Paper", Ashwini A. Chitragar, Sneha M. Vasi, Sujata Naduvinamani, Akshata J. Katigar and Taradevi I. Hulasogi, International Journal on Emerging Technologies (Special Issue on ICRIET-2016)

[29] "Automatic Investigation of Micronutrients and fertilizer dispense System using Microcontroller", Arun M. Patokar; Vinaya Vijay Gohokar, 2018 International Conference on Recent Innovations in Electrical, Electronics & Communication Engineering (ICRIEECE)

[30] "Electrochemical Sensors for Soil Nutrient Detection", IEEE 2018

[31] "Automatic Soil Testing System", Eshwari R Badakh; V. B. Malode, 2020 International Conference on Smart Innovations in Design, Environment, Management, Planning and Computing (ICSIDEMPC)

[32] "Review—The "Real-Time" Revolution for In situ Soil Nutrient Sensing" , Lamar Burton,z K. Jayachandran, S. Bhansali,Journal of The Electrochemical Society, 2020

[33] "IoT Based Real Time Soil Nutrients Detection ", Varsha Kiran Patil; Aniket Jadhav; Someshwar Gavhane; Venkatesh Kapare, Published in: 2021 International Conference on Emerging Smart Computing and Informatics (ESCI)

[34] "Level Identification of Soil pH and Macronutrients using Mobile Application through Image Processing" , 2021 2nd International Conference for Emerging Technology (INCET),John Joshua F. Montanez

[35] "A nutrient recommendation system for soil fertilization based on evolutionary computation" Usman Ahmed a , Jerry Chun-Wei Lin a,* , Gautam Srivastava b,c , Youcef Djenouri, ELSEVIER Journal on Computers and Electronics in Agriculture , published on 31 August 2021

[36] "Predicting Plant Water and Soil Nutrient Requirements", Ana Vesić; Vuk Ignjatović; Sava Lakićević; Luka Lakićević; Bojan Gutić; Hristo Skačev; Dušan Dotlić; Andrej Mićović; Marina Marjanović Jakovljević; Miodrag Živković, IEEE 2020 Zooming Innovation in Consumer Technologies Conference (ZINC)

[37] "Real-Time Monitoring of Soil Nutrient Analysis using WSN", Shylaja S.N, Dr.Veena M.B.International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS-2017)

[38] "Real-time Soil Nutrient detection and Analysis", 2021 International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE), Hema Pallevada , Siva parvathi Potu, Teja Venkata Kumar Munnangi , Bharath Chandhra Rayapudi , Sai Raghava Gadde , Mukesh Chinta

[39] "Smart soil nutrients analysis and prediction of the level of nutrients using a bot", 2019 3rd International Conference on Recent Developments in Control, Automation & Power Engineering (RDCAPE), Nachiket Kulkarni, Amit Thakur, Tanay Rajwa, Prof. Rupali Tornekar, Prof. Saraswati Patil.