"AgroAI: Predictive Soil Analysis and Crop Yield Optimization using Machine Learning"

Atharva Joshi Department of E&TC,Pimpri Chinchwad college ofEngineering and Research, Ravet Pune,India
atharva.joshi_etc2020@pccoer.in

Dnyaneshwari Sahane Department of E&TC,Pimpri Chinchwad college of Engineering and Research, Ravet Pune,India
dnyaneshwari.sahane_etc2020@pccoer.in

Yashika Gujar Department of E&TC,Pimpri Chinchwad college of Engineering and Research, RavetPune,India
yashika.gujar_etc2020@pccoer.in

Prof Priti KaleDepartment of E&TC,Pimpri Chinchwad college of Engineering and Research, RavetPune,India
priti.kale@pccoer.in

Abstract*-Using modern machine learning and AgroAI: predictive soil analysis and crop optimization using machine learning; to revolutionize agriculture. This study predicts the best crops and their potential yields by examining various information about soil, climate and crops. Farmers receive practical recommendations for careful management of resources that promote ecological practices. Ushering in a new era of data-driven agriculture and a more promising agricultural future, "AgroAI" aims to increase productivity, reduce waste and promote sustainable agriculture. AgroAI is an innovative approach to modern agriculture that uses predictive soil analysis and machine learning to achieve optimal yield results. In the face of a growing world population and climate change, AgroAI integrates advanced sensor technologies to collect comprehensive soil data, including nutrient levels, moisture content, pH and temperature. This information forms the basis of an effective machine learning model. Using a combination of supervised and unsupervised learning algorithms, AgroAI predicts yields based on historical data and discovers hidden patterns in soil data. The model is constantly improving its predictions, adapting to changing environmental conditions and evolving agricultural practices. AgroAI is highly adaptable and allows adaptation to different crops, soil types and climates, making it a versatile tool worldwide. The integration of real-time weather data improves its forecasting capabilities, allowing farmers to make informed decisions about irrigation, fertilization and pest control.

Keywords— IOT, Machine Learning, Crop yieldPrediction

1.Introduction

The combination of machine learning and agriculture is aground-breaking collaboration that uses cutting-edge technologies to improve crop prediction and soil analysis. Exact assessments of soil composition, nutrient levels, and moisture content are obtained by use of complex algorithms that process a variety of data sources, including sensors, satellite imaging, and historical records. With the use of these information, farmers can better manage their land and create ideal circumstances for increased crop development. Furthermore, precise predictions of agricultural yields are made possible by machine learning's predictive ability, which takes into account factors like market trends and weather patterns. This helps farmers choose the right crops, plan their planting seasons, and allocate their resources. Farming operations are streamlined by combining these technical developments with agricultural instruments like robots and sensors, which encourages resource efficiency and environmental sustainability. This creative union has the potential to transform conventional farming, promoting resilience, efficiency, and sustainability in the face of constantly changing environmental conditions.

2. Problem Statement

Due to the lack of sustainability and precision in modern agriculture, resources are used inefficiently and yields are uncertain. Farmers want a complete platform that integrates resource optimization, disease detection, crop prediction, and soil analysis. Userfriendliness real-time updates, scalability, user education, and a feedback mechanism are all requirements for this platform. By meeting these needs, farmers will gain the ability to make data-driven decisions, increase production, reduce resource waste, and advancesustainable farming methods.

3. Literature Review

R. Madhumati, T. Arumuganathan and R.Shruthi. Agriculture plays a vital role in the economic development of our country. Crop yield primarily depends on soil fertility and moisture level. Fertilizers are normally recommended based on the nutrient present in the soil. To recommend a suitable fertilizer level, the soil nutrient analysis is essential which is done mostly using laboratory techniques. Manual methods of measuring soil nutrients are time consuming. Many farmers refrain to perform soil testing in the laboratory and grow the same crop in the land continuously, hence soil loses its fertility. A system has been proposed to adopt precision agriculture using Wireless Sensor Networks, which enables remote monitoring of soil fertility and other parameters namely soil moisture, pH and temperature. This data is transmitted to the cloud and the corresponding values are displayed on a mobile application. The proposed Internet of things (IoT) based software system has the intelligence to recommend the quantity of water and fertilizer which improves the quality of the soil and ensures optimum growth of the crop.

\item Arshad, J.; Aziz, M.; Al-Huqail, A.A.; Zaman, M.H.u.; Husnain, M.; Rehman, A.U.; Shafiq, M. (2022). Most people living in developing nations are either directly or indirectly involved in agriculture. The Sustainable Development Goals (SDGs) and engineering technology can work together to create a bridge that will allow farmers to improve their knowledge of agricultural breakthroughs and trends in the next generations. Improved soil preparation, clever irrigation systems, sophisticated techniques for crop nutrient assessment, intelligent fertiliser delivery, and multicropping strategies are some of the next generation trends. In order to optimise yield and achieve sustainability, this work suggests a clever Decision Support System (DSS) that reduces water seepage waste in agriculture and improves per hectare productivity through real-time monitoring. Three fundamental components make up the suggested model: a regulated fertiliser module, a smart irrigation system, and an intelligent sensor module. The system uses networking-based DSS, cloud-based decision support layers, and integrated sensors to suggest precautions for the highest possible sustainable production. With the help of the Serial Peripheral Interface (SPI) communication protocol, the intelligent sensors module's temperature and humidity, NPK, soil moisture, soil conductivity, and pHsensors may send data to the cloud over the internet via Long Range (LoRa) technology. Additionally, an Android application for remote data monitoring based on GPS position and node information has been built. The DSS also takes into account the data that may be obtained from sensors, historical trends, tracking climatic changes, and issuing the necessary warnings for sustainable fertiliser use. The concept is unusual because it integrates smart irrigation with smart control and smart decision-making based on precise real-time field data, as demonstrated by the comparison and findings he gave. Since it uses LoRa, an open-source communication protocol with long-range transmission capabilities up to several kilometres, it performs better than current solutions. By increasing agricultural productivity, the sensor nodes contributed to the achievement of inclusive and sustainable economic objectives.

{P. S. Vijayabaskar} {R. Sreemathi} {E. Keertanaa} The goal of this effort is to build a model for assessing soil fertility. In addition, it recommends the crop that should be planted based on the sensor's value. Additionally, it offers crop-related regional data in the form of a graph. By enrolling for this application, farmers may participate in our farmer chat and exchange ideas with experts. It also implies that in order to raise agricultural yield, fertiliser has to be added to the soil. In order to boost output and profit, itassists farmers in determining the fertility of their yard and helping them grow healthier crops. Additionally, it offers details on the fertilizer that should be incorporated into the soil as well as nearby fertilizer shops.

Joel Cuello, Elmer DADIOS, Ira Valenzuela, and John Carlo Punot 2017 Using the Soil Test Kit (STK) and Rapid Soil Testing (RST) of the Bureau of Soils and Water Management, the nutrients and pH level of the soil were efficiently identified in this study using image processing and artificial neural networks: (1) pH, (2) Nitrogen, (3) Phosphorus, (4) Potassium, (5) Zinc, (6) Calcium, and (7) Magnesium. The soil testing, picture capture, image processing, neural network training system, and outcome components comprise the system's composition. Artificial Neural Networks are used to speed up image processing and provide reliable results. Based on the default MATLAB neural network tool, the system will use 70\% of the acquired picture data for training, 15\% for testing, and 15% for validation. The programme will display the pH and qualitative level of soil nutrients based on the outcome. Overall, it has been demonstrated that this study is accurate in identifying the pH level and soil nutrients.

Potdar Revati, Verma Alok More Pravin Kulkarni, Shirolkar Mandar At the moment, plants must offer enough food to feed a sizable and growing population. The plants must be supplied with soil that contains the right number of nutrients, such as nitrogen (N), phosphorus (P), and potassium (K), in order to achieve a good yield. Numerous techniques, including optical and chemical methods (electrochemistry) have been used to analyse soil nutrients. This research investigated optical methods of soil nutrient detection that are appropriate for developing a portable sensor since they do not require complex sample pretreatments and can directly feel nutrients in dry soil samples. We focus on and go into detail about optical experimentation techniques.

We go from the laboratory testing standards used in India to off-the-shelf techniques like soil testing kits and colorimetric procedures. We also examine the most recent and cutting-edge technical techniques, such as imaging systems, microfluidic, and micro-electromechanical systems (MEMs) based sensors, in addition to the practical and efficient spectroscopic methodologies. The accuracy of sensor results, however, is impacted by environmental conditions that also affect optical approaches. The benefits and drawbacks of optical techniques for soil nutrient monitoring are then covered in this research. It also lists the most recent improvements made to the specified testing technique and provides a brief explanation of how each method operates.

Our goal is for this paper to act as a roadmap for the experimenters and provide guidance for future work that will be needed to develop a portable and effective soil NPK detection sensor.

\item Maria Khaydukova, Dmitry Kirsanov, Julia Ashina, Nabarun Bhattacharyya, Somdeb Chanda, Rajib Bandyopadhyay, Subrata Sarkar, Subhankar Mukherjee, and Andrey Legin. Fertilisers should be carefully added to the soil to help reduce the harmful effects of chemicals on the environment without significantly lowering crop yields. Fertiliser dosages need to be carefully adjusted based on the real nutrient content of the soil and the plants' growing season. These days, the majority of chemical soil analyses are carried out in laboratories, so it is necessary to develop quick and easy analytical tools for this purpose.In this investigation, the N, P, and K concentrations in the soil water extracts were simultaneously measured using a potentiometric multisensor system. It was demonstrated that potentimetric sensors with multivariate data processing can be used to estimate soil sample conductivity and pH in addition to assessing all three macronutrients. Targeted parameters and sensor responses had varying correlation coefficients, ranging from 0.69 to 0.96. With an RMSE of50 mg/kg, N could be quantified within the 60–426 mg/kg range. The suggested method has two main advantages: it requires no reagents and has a short measurement time (8 min for all parameters).

4. Findings from Literature Survey

1. Revati P. Potdar,Mandar M. Shirolkar, Alok J.Vernma ,Pravin S.More & Atul Kulkarn: In order to develop a portable sensor for efficient agriculture, the study analyses optical techniques for soil nutrient detection.Draws attention to the need of soil nutrients for high-yield plants, emphasising the need for simple, direct optical monitoringin dry soil.

Method Progression: Follows the evolution of spectroscopic techniques (e.g., imaging systems, microfluidics, MEMs- based sensors) from complex lab standards to more straightforward kits.Takes into account advantages and disadvantages, pointing out that environmental conditions that impact accuracy can affect optical procedures.

The operating principles, recent advancements, and future directions of the study towards a portable soil NPK sensor are briefly covered.

This methodology thoroughly examines optical soil nutrient detection techniques, examining developments, constraints, and the need for more study to create trustworthy portable agricultural sensors.

2. Rakesh Kumar, M.P. Singh, Prabhat Kumar and J.P. Singh Acknowledges the significance of agriculture for both economic expansion and food security, stressing the difficulty of choosing crops depending on government regulations, market pricing, and production rates.

cites earlier research on yield prediction, machine learning and statistics-based weather forecasting, and crop and soil categorization.The Crop Selection Method (CSM) is proposed as a solution to the crop selection conundrum when presented with a multitude of choices and a restricted amount of land uses CSM to increase crop output rates throughout a season in an effort to boost the nation's economy.predicts that the application of CSM will increase crop production rates, perhaps stimulating economic growth.The main idea behind this technique is to provide the Crop Selection Method (CSM) as a way to optimise crop selection choices while taking into account a variety of elements that affect agricultural planning.

3. Monali Paul, Santosh K. Vishwakarma, Ashok Verma : Outlines a method for predicting the kind of soil datasets, which may be used as a predictor of crop production. For this, the system makes use of data mining techniques defines crop yield prediction as a classification rule issue. Its goal is to categorise soil datasets into groups that correspond to projected crop yields. uses data mining approaches to categorise soil datasets and forecast crop production based on these classifications, including K-Nearest Neighbour and Naive Bayes algorithms, attempts to link possible crop yields with categories in the soil dataset using data mining techniques in order to properly estimate crop output.

4. Aakunuri Manjula, Dr.G .Narsimha:Highlights precision agriculture's technology-driven approach, emphasizing the use of data mining techniques and remote sensing indices like TCI, VCI, and NDVI for crop productivity assessment. Introduces the eXtensible Crop Yield Prediction Framework (XCYPF) designed for flexible and adaptable crop yield prediction, specifically targeting rice and sugarcane crops in precision agriculture. Utilizes remote sensing indices (TCI, VCI, NDVI), along with rainfall data and surface temperature, within the XCYPF framework to predict crop yield for rice and sugarcane. Highlights XCYPF's flexibility in selecting variables, datasets, and indices, emphasizing its adaptability for predicting crop yield in precisionagriculture.

5. Yulong Yin, Hao Ying, Huifang Zheng, Qingsong Zhang, Yanfang Xue, Zhenling Cui:Data collection: 3,896 measurements from various Chinese locations were gathered, with an emphasis on the intake of nutrients above ground to yield 1 mg of rice grain.Specifying the Needs for Nutrients: determined the necessary amounts of N, P, and K depending on growth time, temperature, solar radiation, fertilisation, soil characteristics, and rainfall.

Analysis: These variables' effects on nutritional requirements were examined, with a focus on how they affected rice's needs for N, P, and K.Regional Comparison: This study compared the nutrient needs in northern and southern China, identifying the reasons for the discrepancies in the environments and soil.The updated nutrient needsestimates for rice will help resolve differences in China's nutrient budgets and will enhance agricultural research and policy-making.

6. Maria Khaydukova,Dmitry Kirsanov, Subrata Sarkar, Subhankar Mukherjee,Julia Ashina, Nabarun Bhattacharyya, Somdeb Chanda, Rajib Bandyopadhyay, Andrey Legin:intended to quickly test the levels of potassium (K), phosphorous (P), and nitrogen (N) in soil water extracts using a potentiometric multisensor system.

used a potentiometric multisensor system that could measure pH, conductivity, N, P, and K in soil extracts all at once.

prepared soil water extracts and used the sensor system to test the conductivity, pH, N, P, and K.

Correlation coefficients between 0.69 and 0.96 were obtained by comparing sensor responses with the intended parameters (N, P, and K) in order to evaluate the accuracy ofthe sensor system.

N quantification was accomplished with an RMSE of 50 mg/kg within the 60–426 mg/kg range, indicating accuracy in the measurement of nitrogen.

Benefits that were highlighted were reagentless methodology, which eliminated the requirement for chemical reagents throughout the process, and rapid readings (8 minutes for all parameters).

7. Isaak, Suhaila intended to quickly test the levels of potassium (K), phosphorous (P), and nitrogen (N) in soil water extracts using a potentiometric multisensor system. used a potentiometric multisensor system that could measure pH, conductivity, N, P, and K in soil extracts all at once prepared soil water extracts and used the sensor system to test the conductivity, pH, N, P, and K.

Correlation coefficients between 0.69 and 0.96 were obtained by comparing sensor responses with the intended parameters (N, P, and K) in order to evaluate the accuracy of the sensor system. N quantification was accomplished with an RMSE of 50 mg/kg within the 60–426 mg/kg range, indicating accuracy in the measurement of nitrogen. Benefits that were highlighted were reagentless methodology, which eliminated the requirement for chemical reagents throughout the process, and rapid readings (8 minutes for all parameters).

5. Challenges

AI/ML-based research often lacks practical demonstrations, focusing heavily on theoretical models, hindering the translation of innovations into real-world applications. IoT-based research frequently lacks thorough data analysis, overlooking the potential insights from collected data, while also not emphasizing the efficient integration of hardware and software foroptimal system performance.

6.Conclusion

ML-driven soil analysis and crop prediction use data-driven insights to optimize resource use, improve crop yield estimates, and allow precision farming methods, eventually transforming agricultural efficiency and sustainability. This unique strategy provides farmers with individualized soil management, crop selection, and resource allocation strategies by leveraging advanced algorithms and incorporating cutting-edge technology such as AI analytics, IoT sensors, and robots. This not only increases production, but it also reduces environmental effect by decreasing resource waste and encouraging eco-friendly farming methods. This transformational synergy between machine learning and agriculture has the potential to redefine farming's future by encouraging resilience, efficiency, and environmental consciousness in agricultural landscapes throughout the world.

References

1. Revati P. Potdar,Mandar M. Shirolkar, Alok J.Vernma ,Pravin S.More & Atul Kulkarni (2021) Determination of soil nutrients (NPK) using optical methods: a mini review , Journal of Plant Nutrition,44:12,1826-1839,DOI:10.1080/01904167.2021.18 84702
2. Rakesh Kumar, M.P. Singh, Prabhat Kumar and J.P. Singh (2015), “Crop Selection Method to Maximize Crop Yield Rate using Machine Learning Technique”, International Conference on Smart Technologies and Management for Computing, Communication, Controls, Energy and Materials (ICSTM).
3. Monali Paul, Santosh K. Vishwakarma, Ashok Verma (2015), “Analysis of Soil Behaviour and Prediction of Crop Yield using Data Mining Approach”, International Conference on Computational Intelligence and Communication Networks.
4. Aakunuri Manjula, Dr.G .Narsimha (2015),“XCYPF: A Flexible and Extensible Framework for Agricultural Crop Yield Prediction”, Conference on Intelligent Systems and Control (ISCO)
5. Yulong Yin, Hao Ying, Huifang Zheng, Qingsong Zhang, Yanfang Xue, Zhenling Cui: Estimation of NPK requirements for rice production in diverse Chinese environments under optimal fertilization rates, Agricultural and Forest Meteorology
6. Maria Khaydukova, Dmitry Kirsanov, Subrata Sarkar, Subhankar Mukherjee, Julia Ashina, Nabarun Bhattacharyya, Somdeb Chanda, Rajib Bandyopadhyay, Andrey Legin: One shot evaluation of NPK in soils by “electronic tongue”, Computers and Electronics in Agriculture
7. Isaak, Suhaila et al. “A low cost spectroscopy with Raspberry pi monitoring.” TELKOMNIKA (Telecommunication Computing Electronics and Control) (2019)