

# Phenomenon of Soil Characteristic Digging: Enhancing the Clustering Schemes and Sorting with kNN-Algorithm for Soil Parameter Calculation at KGI Campus.

## Abstract:

Artificial Intelligence augments the domain of precision agriculture by fostering sustainability, enhancing resource allocation, and increasing productivity levels. Methodologies such as machine learning, computer vision, and the Internet of Things (IoT) facilitate the optimization of crop management practices, the identification of plant diseases, and the judicious utilization of resources, thereby responding to the imperative for efficient agricultural practices in the context of escalating global population dynamics and pressing environmental challenges. This study at KGI Campus describes the recent technological development in agriculture as abbreviating NG-AIA: next generation agriculture incorporated with AI. This study describes the different algorithms in AI/ML for agricultural development particularly for soil parameter setting and calculating as it defines the growth of any country's economy.

**Keywords:** AI, IoT, Machine Learning, Smart Agriculture, Soil Parameter, NPK Value, Technological enhancement, kNN-Algorithm.

## Introduction:

Soil is of paramount significance in the domain of agriculture, which in turn is essential for the advancement of a nation. Soil characteristic digging is an art of defining and designing the different soil parameters for more efficient and productive agriculture. Consequently, the analysis of soil parameters is crucial for the enhancement of agricultural productivity. The present investigation concerning soil parameters at the KGI Campus, utilizing Internet of Things (IoT) technology and designing different AI/ML algorithms represents an innovative methodology for environmental monitoring, agricultural planning, and land sustainability (Dey, 2025 ). The condition of the soil is shaped by numerous factors, including moisture, temperature,

30 pH balance, nutrient content, and compaction, all of which later affect the growth of plants,  
 31 retention of water in soil, and the activity of microorganisms. Traditional soil analysis  
 32 methodologies typically involve manual sampling, which is labor-intensive, time-consuming,  
 33 and often fails to capture real-time soil variability (Moharana et al., 2024). This research  
 34 employs IoT sensors for the real-time monitoring of soil health, thereby facilitating efficient  
 35 campus land management and promoting sustainable agricultural practices. Sensors can be  
 36 systematically deployed throughout the campus to create an integrated system that transmits data  
 37 regarding soil moisture, temperature, nutrient concentrations, and pH levels to a central platform,  
 38 where it can be accessed remotely and visualized through dashboards or mobile applications,  
 39 enabling data-driven decision-making by campus researchers, agricultural planners, and  
 40 environmental managers. Moreover, IoT-enabled soil monitoring has the potential to detect  
 41 issues before they manifest, such as nutrient deficiencies and excessive moisture levels that could  
 42 adversely affect plant health or contribute to erosion and other environmental challenges  
 43 associated with soil quality. This study is designed to have create and develop innovative AI/ML  
 44 algorithms that can achieve the objectives of innovation and sustainability regarding smarter soil  
 45 identification within KGI Campus by motivating students and professors to find frontiers in the  
 46 management of resources and environmental science (Sahoo et al., 2024 & Sahoo et al., 2025).  
 47 This study aims to cater to the regional soil analysis based on different AI/ML algorithms for  
 48 data sorting and clustering.

49 **Literature Survey:**

Article	Key Contribution	Key Algorithms	Limitation
<i>K Spandana et al. (2023)</i>	IoT device utilizes various sensors, including soil moisture, pH value, and NPK level sensors, to collect data on soil parameters.	IoT sensor used.	It doesn't support high-end sensors and works only with desktop computer traditional programs. ➤ AI/ML algorithm missing
<i>R. Reshma et al. (2021)</i>	Tracks critical soil parameters like moisture, temperature, pH, humidity, NPK level.	Moisture ,Temperature pH,humidity,NPK level Calculation by IoT sensor.	The systems limitations like sensor accuracy, Internet dependency, high costs, power consumption, and data overload. ➤ AI/ML algorithm missing
<i>Abhijit Pathak et al. (2019)</i>	The various parameters such as temperature, turbidity, pH value,	Temperature, Turbidity	High setup costs challenge effectiveness,

	Moisture has been collected by using Internet of Things (IoT) platform.	pH value, Moisture sensor used.	sensor reliability, internet dependence, regional adaptation needs, and algorithm accuracy.  ➤ AI/ML algorithm missing.
<i>Kuangmin et al., 2018</i>	The paper discusses the limitations of conventional methods in determining soil constitutive model parameters, particularly the influence of artificial experience. It highlights the need for improved efficiency in acquiring multiple constitutive model parameters simultaneously. The use of a fitness function to relate calculation data and test data is emphasized as a key innovation.	Temperature, Turbidity pH value, Moisture sensor used.	The systems limitations like sensor accuracy, Internet dependency, high costs, power consumption, and data overload. ➤ Major AI/ML algorithm missing.
<i>Dey et al., 2025</i>	Tracks soil parameters like moisture, temperature, pH, humidity, NPK level.	Moisture, Temperature pH, NPK level calculation based on IoT sensor.	The systems limitations like sensor accuracy and Internet dependency. ➤ Major AI/ML algorithm missing.
<i>Bayram et al., 2025</i>	Soil analysis with machine learning approach predicts different parameters of soil for better soil productivity.	Used different algorithms of ML for clustering and data analysis.	Comparative analysis missing and Major algorithm comparison for different soil samples like multi-regional and multi seasonal is missing.

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**Table 1: Key Literature Survey**

52 The above literature survey suggests that a systematic approach in regional soil parameter  
53 analysis is missing and for better productivity and efficient NG-AIA (next generation agriculture

54 incorporated with AI) the multi regional data analysis is required (Dey et al., 2024). This paper  
55 caters to the study of different soil parameters and their clustering on the basis of specific data.

### 56 **Research Gap in Existing Studies:**

57 Enhanced agricultural productivity can be attained with diminished requirements for water,  
58 fertilizer, and fuel. Concurrently, an increased number of crops may be cultivated within reduced  
59 spatial confines, thereby lessening the financial burdens on farmers. The utilization of big data  
60 analytics facilitates the examination of factors such as climatic conditions and soil fertility,  
61 consequently refining agricultural processes. At this juncture, machine learning (ML)  
62 methodologies assume a pivotal role in the analysis and forecasting of data. Therefore,  
63 advancements extending from digital innovations to autonomous systems are being integrated  
64 into the realm of smart agriculture by the help of different innovative AI/ML algorithms.

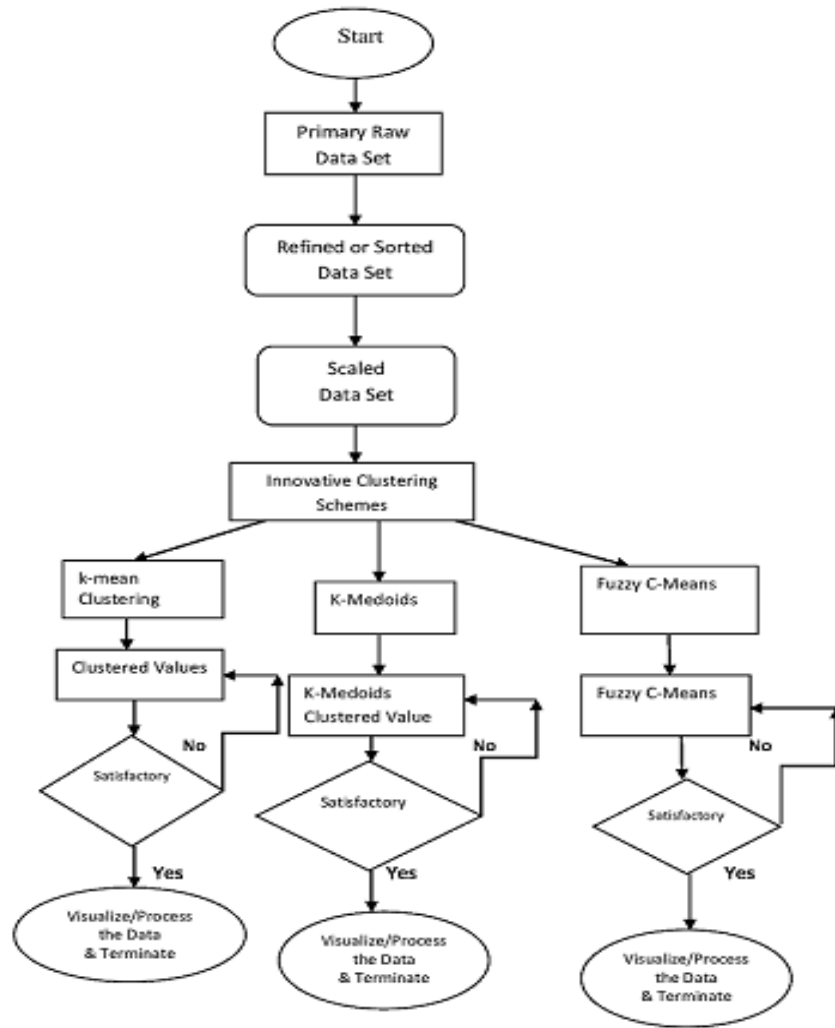
- 65 • As an illustration, Reddy et al. (2019) established a crop recommendation framework that  
66 incorporates machine learning algorithms in the Ramtek area of India. But there is a huge  
67 gap in finding out proper ML algorithm efficiency in enhancing productivity.
- 68 • Garanayak et al. (2021) conducted an analysis of climatic and edaphic data utilizing  
69 machine learning regression techniques to enhance soil fertility in the Andhra Pradesh  
70 region. But some specific data set is used to carry out the regression techniques which  
71 again has a huge research gap in analysing the soil fertility considering multiple parameters  
72 like pH value, moisture level and sand percentage etc.
- 73 • Paudel et al. (2022) introduced regional machine learning models for the prognostication  
74 of crop yields across multiple spatial dimensions. Patel and Patel (2023) sought to  
75 augment crop yield and optimize resource utilization through machine learning  
76 methodologies in Gujarat.
- 77 • Bhargavi and Jagannathan (2024) leveraged meteorological, soil, and locational data to  
78 forecast crop yields in the Maharashtra and Karnataka regions. These all are recent  
79 developments in soil parameter calculations and soil productivity enhancement through  
80 ML algorithms. But there is a huge research gap in calculating the efficiency of these  
81 algorithms and their practical implementations.
- 82 • Dey et al. (2024 & 2025), performed soil parameter calculations in different climate and  
83 temperature levels in Odisha KGI campus via IOT sensor but there is a huge gap in

84 evaluating some specific algorithm based soil data clustering and evaluation in odisha  
85 region incorporating AI/ML algorithms.

- 86 • This study caters to analyze the different AI/ML algorithm like random forest (RF), k-  
87 Mean clustering, and decision tree algorithms for soil parameter calculation and fin ding  
88 out the best one amongst them. This study has enormous data set for evaluating suitable  
89 parameters for suitable or intelligent agriculture. Therefore, assessment is vital for critical  
90 and sustainable agriculture.
- 91 • Soil fertility exhibits regional variability, necessitating the selection of crops in  
92 accordance with these differences. Established studies have scrutinized the factors that  
93 determine soil fertility in various nations. Nonetheless, there is a scarcity of research that  
94 meticulously classifies soil characteristics in odisha via machine learning algorithms. A  
95 detailed examination of soil analysis data from odisha at KGI campus, along with their  
96 classification through machine learning techniques, is an essential research priority.

#### 97 **Research Methodology and Subsequent Process Flow:**

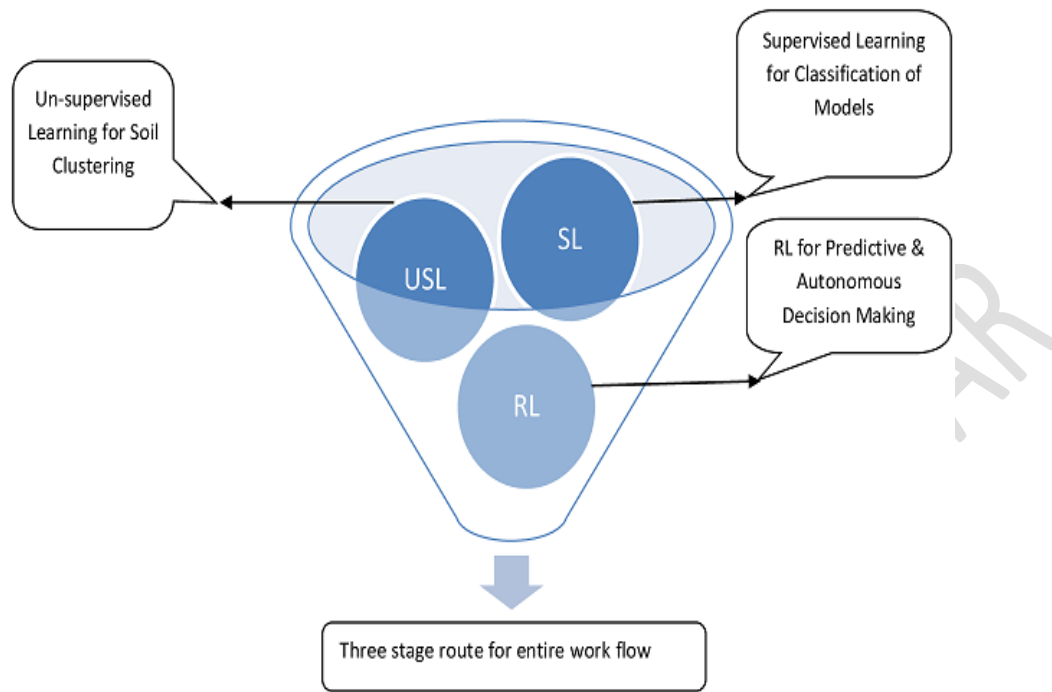
98 This research utilized soil analysis data from Dey et al., 2025 from odisha KGI campus. The  
99 soil's physical and chemical elements (e.g., soil pH, moisture levels, overall salinity, sand, clay,  
100 sodium, potassium, phosphorous value, saturation, and various other factors) were taken into  
101 account. Initially, the K-means clustering method was utilized to categorize soils, facilitating  
102 significant differentiation and assessment of fertility levels. Subsequently, these clusters served  
103 as labels for training supervised machine learning models. The goal was to anticipate the group  
104 of a randomly chosen soil sample. The results are anticipated to assist farmers of odisha region  
105 with soil management techniques and aid in upcoming research. In this context, this research  
106 seeks to offer advantages like precise crop choices for farmers, promoting sustainable farming  
107 methods, averting soil degradation, lowering expenses, choosing correct soil factors with  
108 required percentage through optimal land utilization, and diminishing environmental effects. The  
109 entire research methodology has been designed through the following flowchart.



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111 Figure 1:Flow Chart for Innovative Clustering Schemes used in Soil Analysis at KGI campus.

112 Figure 1 describes about the innovative clustering schemes used in soil analysis at KGI campus  
 113 with mainly three proposed methodologies, k-mean clustering, k-medoids and fuzzy C-means.  
 114 The k-mean clustering is used for clear boundaries of datas whereas fuzzy C-mean schemes are  
 115 used for unclear boundaries of data's. But k-medoids clustered scheme is used here based on  
 116 physico-chemical properties or spatial distribution. Each phase has opportunity to get refined  
 117 data with the process of feedback and proceed for next level. Figure 2 explains the soil  
 118 characteristic digging workflow which designs the system a robust one for soil clustering by the  
 119 help of supervised, unsupervised and reinforced machine learning schemes. The soil  
 120 characterization is passed through a dedicated three stage route for future decision making.



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Figure 2: Soil Characteristic Digging Workflow

123 Figure 3 studies about the innovative AI/ML algorithm used in the process of data splitting,  
 124 grouping and sorting. Data splitting, sorting and grouping is again made via training and testing.  
 125 In training phase different algorithms like random forest, logical regression, decision trees, and  
 126 kNN is used to evaluate a proper training model while in testing phase model performance is  
 127 evaluated based on benchmarking. The data set here is used from the previous project at the KGI  
 128 campus (Dey et al., 2025). The data set includes physical and chemical properties of soil samples  
 129 collected from various locations of KGI campus and it's in and around locations. Parameters like  
 130 saturation with water, pH percentage in water saturated soil, total salt percentage, sand  
 131 percentage, clay percentage and NPK values etc. The proportions and descriptive statistics are  
 132 listed in a table below after averaging out from the random values. This study has five soil  
 133 samples like KGI soil sample1, KGI soil sample2, KGI soil sample3, KGI soil sample4, KGI soil  
 134 sample 5. Sample 6 is calculated as the average of all samples from KGI 1, KGI 2....to KGI 5.  
 135 Finally after all the process of training and testing, the soil quality categorization is done ranging  
 136 from Quality 1 to Quality N.

Parameter	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average
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Saturation with water (%)	83.294	86.456	82.334	84.394	84.284	84.152
pH in water saturated soil	7.62	7.73	7.34	7.69	7.61	7.598
Total salt (%)	0.031	0.029	0.034	0.028	0.031	0.0306
Sand (%)	30.814	31.35	30.754	31.24	31.025	31.036
Clay (%)	44.45	46.35	43.55	45.25	45.35	44.99
N	11	12	11	11	11	11
P	12.55	12.75	12.05	12.70	12.70	12.55
K	41.75	42.65	40.55	42.75	42.75	42.09

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Table 1: Different Soil Sample at KGI campus.

<b>KGI Soil Sample Characteristics</b>	<b>Average Value</b>
Saturation with water (%)	84.152
pH in water saturated soil	7.598
Total salt (%)	0.0306
Sand (%)	31.036
Clay (%)	44.99
N	11
P	12.55
K	42.09

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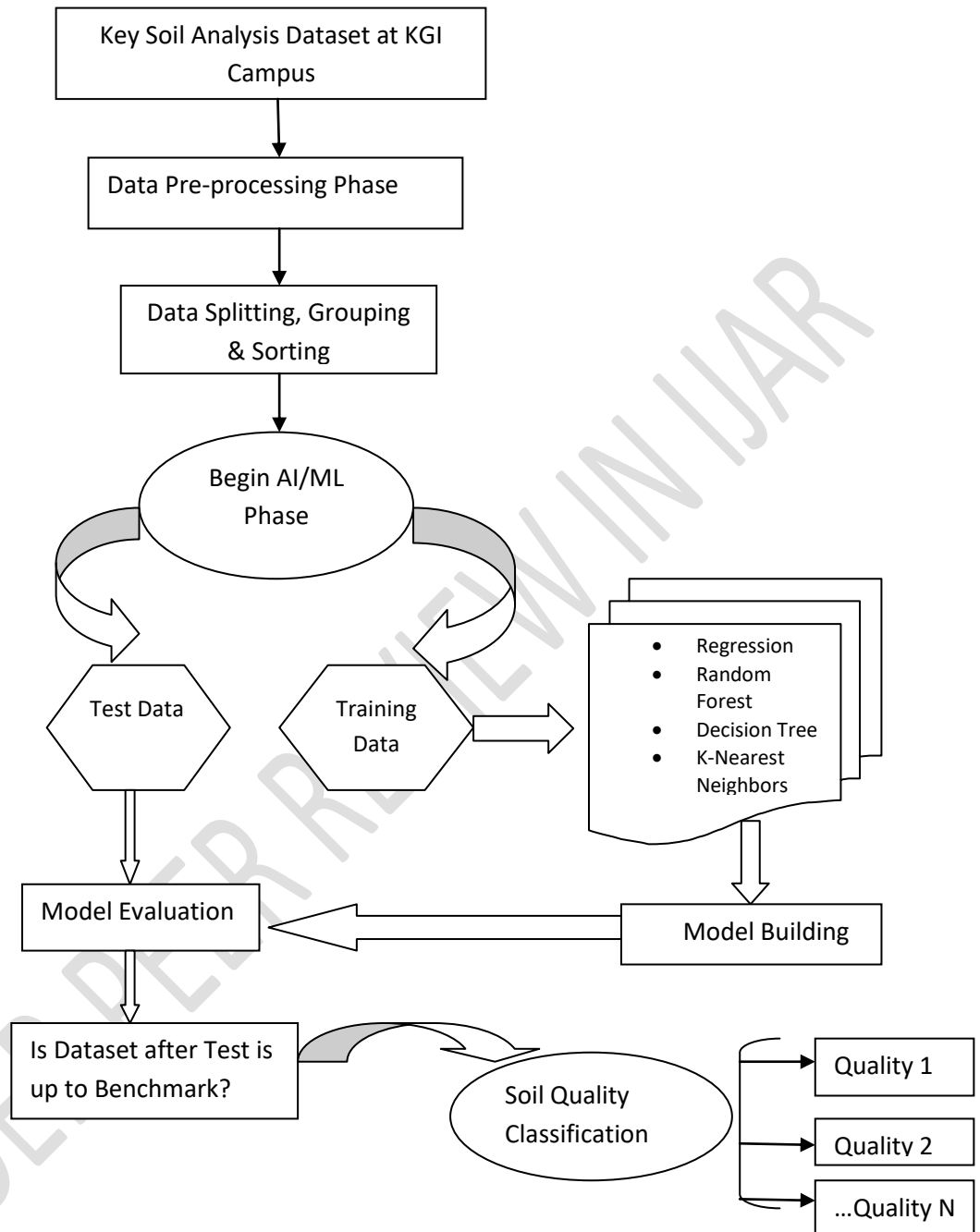
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Table 2: Soil Sample Average Values at KGI.

141 Table 1 and Table 2 provides the different soil samples at KGI campus with five samples as  
 142 sample 1, sample 2, sample 3, sample 4 and sample 5. An average value is calculated after  
 143 accumulating every samples together. The average pH value is 7.598 which is mildly alkaline.  
 144 Total percentage of salt content is low at about 0.0306%. The sand and clay proportions are  
 145 31.036% and 44.99% respectively. The value of N, P and K is averaged out to be at the lower  
 146 side (Dey et al., 2023). So, these soil statistics show that the soils at KGI campus have a  
 147 heterogeneous physical and chemical structure and their diversity will make a right decision to  
 148 incorporate the machine learning schemes here.

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150 **AI/ML Schemes for Soil Analysis Model Building:**



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Figure 3: Model Evaluation Process incorporating Innovative AI/ML schemes.

153 As per figure 3, a soil characteristic analysis model has been proposed incorporating different  
 154 AI/ML schemes. Algorithms like regression, random forest, decision tree and k-nearest  
 155 neighbors are the building blocks of this model which are helpful in model training and  
 156 evaluation. Subsequent soil quality classification is deployed as per the evaluation is done which  
 157 tests the benchmark and defines the quality from quality 1 to quality N. Data clustering is done  
 158 through the methods like k-means clustering, logistic regression algorithm and decision tree  
 159 algorithm. The most important advantages of decision tree are its interpretability but they are

160 very sensitive to noise and susceptible to over fitting. Decision trees are generally combined with  
161 random forests to provide effective accuracy and higher rate of generalization. Decision tree is  
162 the stand out algorithm which has been incorporated as valuable ML algorithm for the effective  
163 uses in healthcare, agriculture and environmental studies. Figure 4 shows the soil analysis  
164 arrangement procedure in KGI campus.



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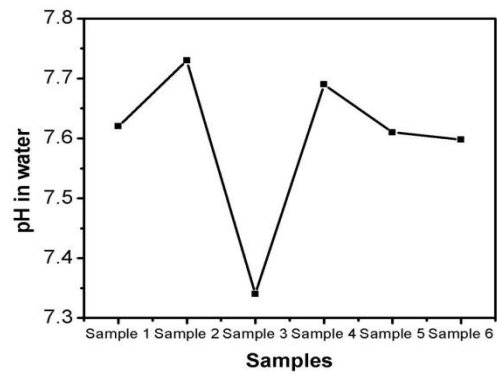
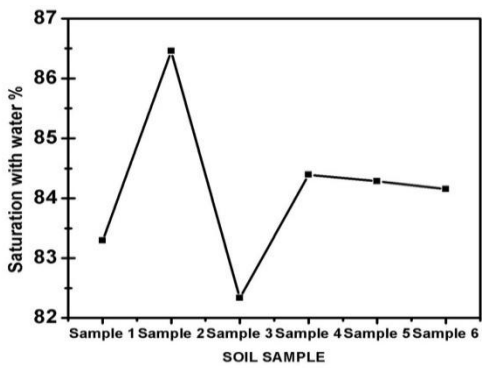
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Figure 4(a, b, c): Systematic Arrangements of Soil Characteristic Analysis

168 **Results and Discussion: -**

169 A systematic arrangement of five different soil samples and subsequent average value calculation  
170 after optimization shows that the average pH value is 7.598 which is mildly alkaline. Total  
171 percentage of salt content is low at about 0.0306%. The sand and clay proportions are 31.036%  
172 and 44.99% respectively. The value of N, P and K is averaged out to be at the lower side. So,  
173 these soil statistics show that the soils at KGI campus have a heterogeneous physical and  
174 chemical structure and their diversity will make a right decision to incorporate the machine  
175 learning schemes. For fertility and effective soil, the incorporation of different ML schemes will  
176 give optimized value of these characteristics to choose right soil for quality assurance. The  
177 values are plotted as per graph shows where sample 6 of each plot shows the average value of  
178 that soil parameter.

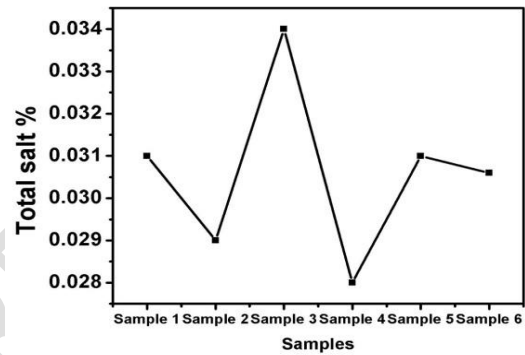
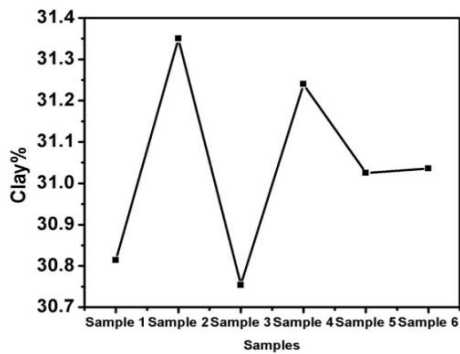


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(a)

(b)

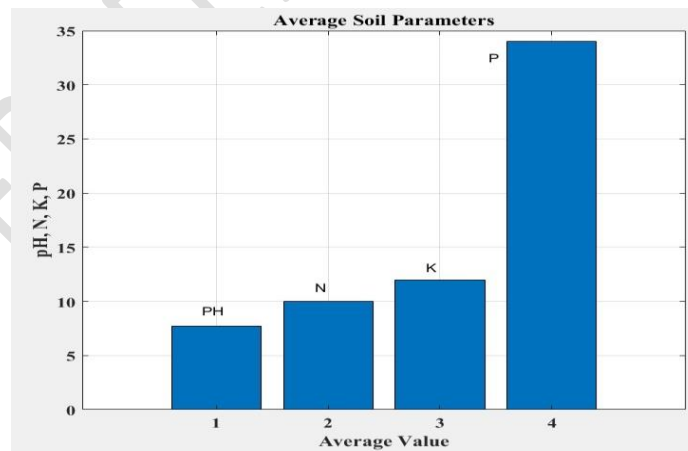


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(c)

(d)



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(e)

185 Figure 5 (a, b, c, d, and e): Soil Parameter Values with Respect to Different KGI Samples.

186 **Soil Fertility ML Workflow at KGI Campus:**

## 187 1.Data Collection & Preprocessing

- 188 • Gather soil parameters: pH, salinity, sand/clay %, NPK values, organic matter, moisture.
- 189 • Clean data: handle missing values, normalize ranges (e.g., scale pH between 0–14).
- 190 • Feature engineering: derive indices like fertility score, water retention index.

## 191 2. Exploratory Data Analysis (EDA)

- 192 • Visualize distributions (histograms for pH, salinity).
- 193 • Correlation analysis (e.g., NPK vs fertility).
- 194 • Cluster soils into groups (heterogeneous patches).

## 195 3. Model Selection

- 196 • **Classification Models:**
  - 197 ○ Decision Trees / Random Forests → classify soils into fertility categories (low,
  - 198 medium, high).
- 199 • **Regression Models:**
  - 200 ○ Linear Regression / Gradient Boosting → predict crop yield or nutrient
  - 201 availability.
- 202 • **Clustering:**
  - 203 ○ K-means / Hierarchical clustering → group soils with similar properties.
- 204 • **Optimization:**
  - 205 ○ Genetic Algorithms / Bayesian Optimization → suggest best soil-crop-fertilizer
  - 206 combinations.

## 207 4. Training & Validation

- 208 • Split dataset (train/test).
- 209 • Use cross-validation for robustness.
- 210 • Evaluate with metrics: accuracy (classification), RMSE (regression).

## 211 5. Deployment

- 212 • Build a decision-support dashboard for campus soil management.
- 213 • Input: soil sample data.
- 214 • Output: fertility score, crop recommendation, fertilizer plan.

## 215 6. Continuous Improvement

- 216 • Retrain models with new soil samples each season.
- 217 • Incorporate external data (weather, crop performance).
- 218 • Feedback loop: compare predicted vs actual yields.

## 219 Example Use Case

- 220       • Input: Soil sample with pH 7.6, clay 45%, NPK low.  
221       • ML Output: Fertility = “Moderate,” Recommended crop = “Legumes,” Suggested  
222       intervention = “Organic compost + phosphorus fertilizer.”

### 223 **Future Research:**

224 The prospective advancements in Artificial Intelligence (AI) and Machine Learning (ML) hold  
225 the potential to render soil analysis both precise and universally attainable, whilst ensuring  
226 sustainability. The following delineates several pathways for future exploration.

227 **Hybrid Methodologies of AI Frameworks:** The integration of conventional soil science with  
228 AI methodologies, which entails the utilization of hybrid models that amalgamate the intrinsic  
229 physical characteristics of soils with predictive analytics derived from AI, significantly augments  
230 the precision and flexibility of the model. For instance, physics-informed neural networks,  
231 grounded in the foundational principles of both soil and environmental sciences, may yield  
232 enhanced predictive capabilities concerning the behavior of soils across varying environmental  
233 conditions.

234 **Edge AI:** Edge AI denotes the computational processes conducted on devices, including  
235 sensors, as opposed to utilizing cloud-based servers. This technology possesses the capacity to  
236 deliver instantaneous soil assessments while minimizing both latency and energy consumption.  
237 Given its ability to lessen reliance on continuous internet connectivity, it proves to be  
238 exceedingly advantageous for regions characterized by remote or limited connectivity.

239 **Variiegated Dataset Integration:** Combining various datasets, including remote sensing, soil  
240 sensors, and GIS data, to provide a comprehensive view of soil characteristics.

### 241 **Conclusion:**

242 The different soil parameter analysis at KGI campus shows that the average pH value is 7.598  
243 which is mildly alkaline. Total percentage of salt content is low at about 0.0306%. The sand and  
244 clay proportions are 31.036% and 44.99% respectively. The value of N, P and K is averaged out  
245 to be at the lower side. So, these soil statistics show that the soils at KGI campus have a  
246 heterogeneous physical and chemical structure and their diversity will make a right decision to  
247 incorporate the machine learning schemes. For fertility and effective soil, the incorporation of  
248 different ML schemes will give optimized value of these characteristics to choose right soil for  
249 quality assurance.

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