



## FertiCal-P: An Android-based Decision Support System (DSS) Determines the NPK Fertilizer Recommendation by Assessing pH and Macronutrient of the soil

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### Abstract

The agriculture industry faces the challenges due to uncertainty, including unpredictable weather, rainfall, and improper crop and soil selection. Precision agriculture (PA) has mitigated these issues by monitoring and responding to crop variability. This paper offers the FertiCal-P App, an Android-based fertilizer calculator that recommends the NPK fertilizer requirements based on soil test data, such as N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O, and pH, to optimize crop yields and illustrate precision agriculture practices. The FertiCal-P App is developed using rule based and regression techniques and it calculates three different fertilizer recommendations, which are combinations of three chemical fertilizers out of five in two stages: the first at sowing and the second after 30 days of sowing, which ensuring optimal fertilizer efficiency, reduced fertilizer usage, lower cost and ultimately adverse impact on environment. The app's last screen indicates price breakups, which assist farmers in reaching financial and agronomical decisions. Further, we will need to test this approach at the district level in Gujarat prior to rolling out it across the Indian sub continent.



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### Keywords

Chemical Fertilizer;  
Fuzzy Rule;  
Precision Agriculture;  
Regression;  
Soil Fertility.

### Abbreviations

Al	-	Aluminium
ATP	-	Adenosine Tri-Phosphate
DAP	-	Di-Ammonium Phosphate
DSS	-	Decision Support System
EC	-	Electrical Conductivity
FertiCal-P	-	Fertilizer Calculator in context to Soil pH.
IoT	-	Internet of Thing

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K <sub>2</sub> O	-	Potassium Oxide
KCL	-	Potassium Chloride
Kg Ha <sup>-1</sup>	-	Kilogram per Hectare
K <sub>2</sub> SO <sub>4</sub>	-	Potassium Sulfate
ml	-	Mili litre
MOP	-	Muriatic of Potash
N	-	Nitrogen ions
NH <sub>4</sub> <sup>+</sup>	-	Ammonium Ions
NPK	-	Nitrogen-Phosphorus and Potassium nutrients
NO <sub>3</sub> <sup>-</sup>	-	Nitrate ions
NO <sub>2</sub> <sup>-</sup>	-	Nitrites ions-
P <sub>2</sub> O <sub>5</sub> <sup>-</sup>	-	Phosphorus Pentoxide
PA	-	Precision Agriculture
pH	-	Logarithmic scale which measure acidic or alkaline properties of matter
S-	-	Sulpher
SSP	-	Super Single Phosphate

### Introduction

Modernization and urbanization have improved human comforts, but they have also reduced the available resources for food production due to shrinking available fertile land and massive deforestation.<sup>1</sup> In the last fifty years, the world's population has increased 2 to 2.5 fold, yet food grain production has not kept pace with this demand.<sup>2</sup>

Farmers have long engaged in the practices of ploughing, fertilization and irrigation, (which are referred to as "Khed, Khatar ane Pani" in Gujarati) in order to cultivate food grain across the Indian continents and also throughout the world.<sup>3</sup>

It has been proved that at each and every stage of crop life cycle,<sup>4-5</sup> these farming methods are impacted by the presence of uncertainties<sup>6</sup> When looking for the solution, we found that the agriculture industry and its allied practices faced a significant challenges due to the inherent uncertainties associated with it.<sup>7-8</sup> Advances in computational power, based on engineering solutions, have greatly reduced the consequences of such uncertainty in agriculture.<sup>9-10</sup> The effects of such uncertainty in agriculture have been significantly mitigated as a result of developments in computational tools and techniques, also known as Precision agriculture (PA).<sup>11</sup> Precision agriculture is the farming practice that monitors, measures, and responds to crop variability<sup>12-13</sup> and it uses the 5 R's with the aim of applying the right inputs, at the right amount, to the right place, at the right time, and in the right manner.<sup>14</sup>

The objective of precision agriculture research is to develop a decision support system<sup>15-16</sup> (DSS) that enables comprehensive farm management, with the aim of optimizing input yields and preserving the environment,<sup>17-19</sup> Precision Agriculture offers an ideal solution by employing specialized equipment, software, and services<sup>20-21</sup> The development and application areas of an expert DSS for agriculture encompass a wide range of farming activities, such as irrigation scheduling, farm management, disease identification and forecasting, and nutrition and fertilizer advisory<sup>22</sup>

### Soil Fertility

Precision agriculture focuses on evaluating soil variabilities such as nature and different properties,<sup>23</sup> and implementing various tools and techniques<sup>24</sup> listed below to achieve this.

- physio-chemical properties of soil (pH, EC, etc.)
- availability of macro- and micronutrients and other ions in the soil
- moisture and water holding capacity of the soil and
- organic matters and microbial populations

Nutrition and fertilizer advisory services, assessed for soil fertility and optimized it for crop production, are crucial components of sustainable agriculture.<sup>25-27</sup> The one of the goal of precision agriculture is to intensively offer suitable fertilizer types and doses, resulting in efficient sources of nutrients for achieving profitable yields.

The optimal growth and yield of food crops necessitate the presence of seventeen essential nutrients in the soil, which should be available to plants and these are characterized into two categories such as Macro and Micronutrients. Macro nutrients are further divided into two; the primary macronutrients (N), (P), and (K). secondary nutrients, including (S), (Ca), and (Mg), are to be applied in huge quantity as  $\text{Kg Ha}^{-1}$ , while micronutrients (Cu), (Mn), (Co), (B) (Zn), (Mo) and (Fe) should be provided as minor quantity ppm concentration. These nutrients must be present in the soil at levels that are sufficiently bioavailable for plant uptake, as well as plant tissue. The soil physio-chemical properties, such as pH, organic matter, cation exchange capacity (CEC), the presence of anions that interact with specific cations, and soil moisture content, influence the uptake of nutrients from the soil<sup>28</sup>

Soil fertility testing is the prime objective of nutrition and fertilizer advisory which can be obtained by online or offline, Online remote sensing, wireless sensor networks and IoT's and also spectroscopy and colorimetry are used in soil fertility tests, but the software and diagnostic tools used are not perfect. Offline mode will be accurate the process takes long time to do a soil fertility test, and we have to do field tests, soil sampling,<sup>29</sup> a wet chemistry laboratory approach with the equipments, sensor meters, colorimetry, and spectroscopy.

### Chemical Fertilizer

Chemical fertilizers are inorganic forms that are applied to soil or directly to plants to provide nutrients for optimum plant development and growth.<sup>30-31</sup> Three categories are there

- one is straight fertilizers which include only one primary plant nutrient, (N or P or K) such as and potassium chloride
- complex fertilizers in which two basic nutrients are chemically combined. such as diammonium phosphate (DAP) and ammonium phosphate. and finally
- mixed fertilizers two or three major plant nutrients.

Chemical fertilizers are often accessible in granular form with water-soluble properties; however, a few chemical fertilizers are also in liquid form.

### Nitrogen Fertilizer

Nitrogen (N) is a vital nutrient for plants at all stages of their life cycle encompassing sowing, seedling development, sprouting, and vegetative growth. It is often asserted that all plants rely on it for survival. Nitrogen is crucial for chlorophyll synthesis, protein formation, and the generation of nucleic acids and amino acids, during the plant's life cycle. Plants need mineral nitrogen and are absorbed from the soil in the form of nitrates ( $\text{NO}_3^-$ ), nitrites ( $\text{NO}_2^-$ ), and ammonium ( $\text{NH}_4^+$ ) ion.<sup>32</sup> A very small amount of organic nitrogen can be present in humus, living organisms, or as intermediate products of organic matter decomposition. Microorganisms transform organic nitrogen into ( $\text{NH}_4^+$ ) and subsequently into nitrates ( $\text{NO}_3^-$ ). is used directly in plants, and is not lost from the soil as easily as  $\text{NO}_3^-$  ions. Plants require nitrogen for uptake of nitrate from ammonium nitrate fertilizer (fast rate application) and uptake of ammonium ( $\text{NH}_4^+$ ), from urea fertilizer (slow rate application).

### Phosphorus Fertilizer

Phosphorus<sup>33</sup> is involved in many plant processes, such as energy transfer reactions, development of reproductive structures, crop maturity, and root growth protein synthesis. Despite the low concentration of phosphate in soil solutions, plants take up a substantial amount of P due to desorption and dissolution, followed by diffusion to the plant root. Single superphosphate (SSP) is: the first commercial fertilizer for treating soil phosphorus deficiency followed by DAP fertilizer, comprising 18% N and 46% P of phosphorus. It also contains 2.5% sulphur.

### Potassium Fertilizer

Potassium ( $\text{K}_2\text{O}$ ) is another macronutrient that plants need in large amounts for growth, and its requirement can be as high as that of nitrogen. Potassium nutrients required to plants for photo synthesis, ATP production, translocation of sugar, starch Production, nitrogen fixation in legumes, protein synthesis.<sup>34</sup> Plant uptake only soluble k (1 to 10mL) and exchangeable K. Numerous factors influence potassium absorption by plants, including soil moisture, soil aeration or oxygen concentration, soil temperature, and tillage practices. The requisite quantity of potassium fertilizer is contingent upon the soil type and the crop cultivated. Muriate of potash

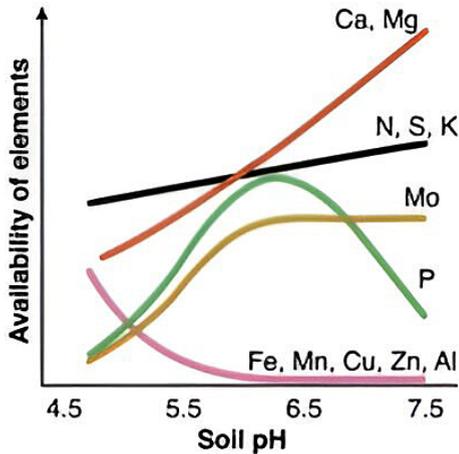
(KCl) and sulphate of potash ( $K_2SO_4$ ) are commonly used potassium fertilizers.

**Soil pH**

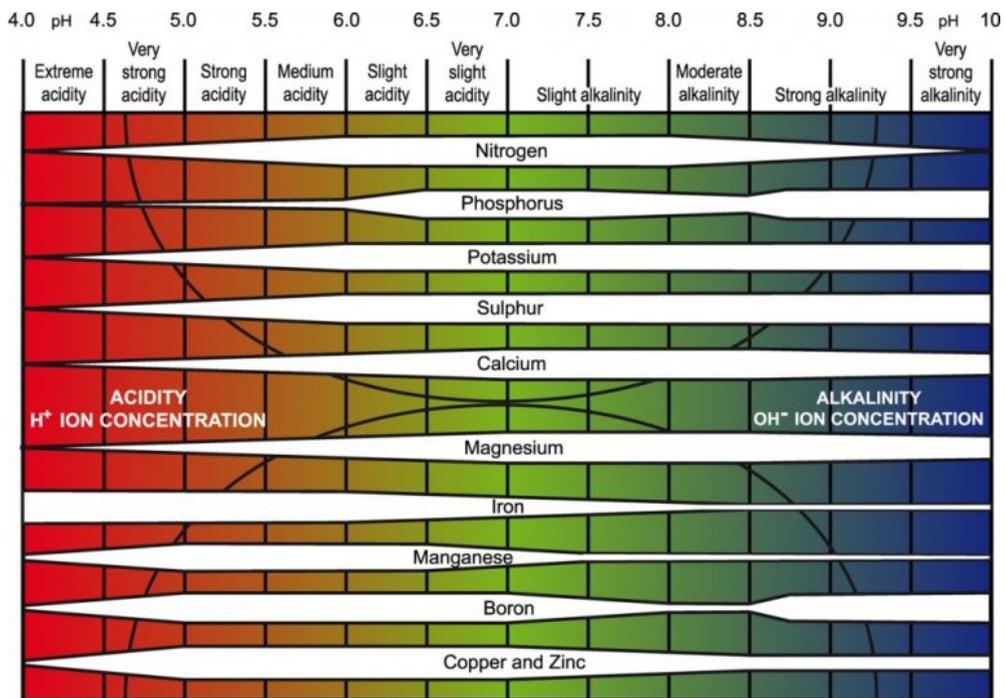
The pH of a prime soil property has a significant impact on the types and amounts of critical nutrients that are accessible to plant roots.<sup>35</sup> Soil pH reaction is the key to plant nutrient availability in the soil

which regulates the plant's nutrient fixation, and their release, and availability. In very acidic soil, Al and Mn may become more accessible and more poisonous to plants, whereas Ca, P and Mg are less accessible. In very alkaline soil, phosphorus and most micronutrients exhibit reduced availability.

Each plant should adhere to a specific pH value range. Due to the fact that pH has an effect on the availability of nutrients within the soil,<sup>37</sup> and plants have varying nutrient requirements, refer fig-1. When the pH value of the soil is more than 5.5, highly critical nutrient for plants, is readily available in the soil. Because of this, nitrogen has the potential to be transformed into a gas that has a pH value that is higher than 7.2, the availability of the phosphorus occurs when the pH value is between 6 and 7. Hence, planting of suitable crops in specific pH is necessary to avoid the deficiency as well as disease occurrence It is advisable to maintain the pH of the soil between 4.5 and 8.8, which will make exchangeable  $K^+$  available for plant uptake. The optimal pH value range for soil is approximately between 6 and 7.2, according to experts.<sup>38-39</sup>



**Fig. 1: Availability of soil nutrients versus soil pH<sup>36</sup>**



**Fig. 2: How Soil pH affect the availability of Plant Nutrients<sup>38,39</sup>**

This study work uses soil pH as a secondary variable to ascertain the requirements for N, P, and K fertilizers by employing regression and rule-based methodologies.<sup>40-42</sup>

**Materials and Methodology**

**The FertiCal-P App**

This paper implements a comprehensive framework to calculate the soil's need for NPK fertilizer for optimal crop yields and demonstrates precise farming practices.<sup>43-45</sup> The FertiCal-P App (Fertilizer calculator in context to soil pH) is an Android-based

chemical fertilizer recommendation calculator that estimates the need for NPK fertilizers based on soil test data like N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O, and pH. Small farmers rarely use commercial software to estimate the need for fertilization for various reasons; the FertiCal-P App is available for free installation on playstation. Farmers can use it to determine the requirements for NPK fertilizer by comparing the price breakdown presented on the app's last screen, making it the most adaptable solution. As a result, it meets the objective by offering improved decision support to the end users.

**Table 1: Fuzzy Rule for Clustering**

Available Fertilizer in soil Kg Ha <sup>-1</sup>	Case-I	Case-II	Case-III	Case-IV	Case-V
Nitrogen	0 to 100	101 to 200	201 to 300	301 to 400	401 to 500
Phosphorus	0 to 15.00	15.01 to 30	30.01 to 45	45.01 to 60	60.01 to 75
Potassium	0 to 75	76 to 150	151 to 225	226 to 300	301 to 375
Attributes	Very low	Low	Moderate	High	Very High

**Methodology**

The FertiCal-P App has implemented procedure as indicated in table-1 to calculate the need for NPK fertilizer recommendations based on soil test values for nitrogen (N), phosphorus (P<sub>2</sub>O<sub>5</sub>), and potassium (K<sub>2</sub>O), in context to soil pH. The following are the detailed procedure to work out the fertilizer dose using this app.

**Step-1**

Evaluate the Total need of nutrients of the soil.

Find the appropriate case constant by comparing soil nutrients test values and ascertain total need of nutrients from chemical fertilizers (T<sub>NR</sub>) for N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O.

$$T_{NR} = D_{NR} + S_{NR}$$

Where

D<sub>NR</sub> = Deficient of Macronutrients in the soil

T<sub>NR</sub> = Total Macro-nutrients to be required for optimal Yield

S<sub>NR</sub> = Macro-nutrients available in the soil (Test data)

**Step-2**

Find the deficient of nutrients of the soil

$$D_{NR} = A_{\text{case constant}} + ( B_{\text{case coefficient}} - SNR )$$

Where

A<sub>case constant</sub> = Case wise constant of the respective nutrients

B<sub>case coefficient</sub> = Case wise co-efficient of the respective nutrients

**Step-3**

Estimate Macro Nutrients to be required in context to soil pH.

$$FNR = D_{NR} \times S_{pH}$$

Where

F<sub>NR</sub> = Final Macronutrients (N,P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O) to be required

S<sub>pH</sub> = pH of the soil

Soil pH affects linearly the requirements of soil nitrogen (N) and soil potassium (K<sub>2</sub>O), but it also

changes both sides from the peak of about pH of 6.32 for phosphorus (P<sub>2</sub>O<sub>5</sub>).

**Step-4**

Calculate Chemical fertilizer Recommendation (N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O) for estimated F<sub>NR</sub>.

Urea (46:0:0) recommendation for N = F<sub>NR</sub> x 2.17 Kg Ha<sup>-1</sup>

SSP (016:0:0)\* recommendation for P<sub>2</sub>O<sub>5</sub> = F<sub>NR</sub> x 6.25 Kg Ha<sup>-1</sup>

MoP (0:0: 60 ) recommendation for K<sub>2</sub>O = F<sub>NR</sub> x 1.7 Kg Ha<sup>-1</sup>

DAP (18: 46:0) recommendation for P<sub>20%</sub> = F<sub>NR</sub> x 2.2 KgHa<sup>-1</sup> and for N = F<sub>NR</sub> x 5.55 Kg

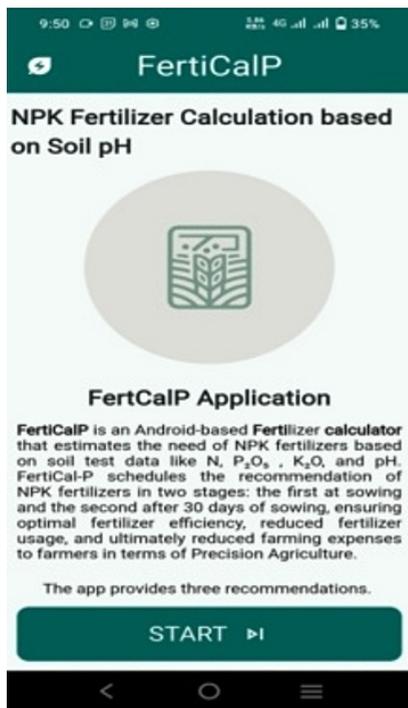
Ha<sup>-1</sup> and NPK (18:18:18) recommendation for N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O = F<sub>NR</sub> x 5.55 KgHa<sup>-1</sup>

**Description of FertiCal-P App**

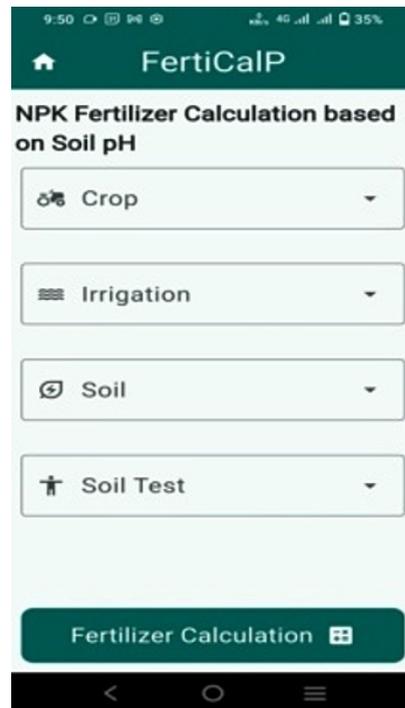
The interface of The FertiCal-P App is built in the form of tabs. Calculations are performed automatically after the user has entered the required soil test data. The Fertilcal-P App launched on the Android phone and displayed the main menu, as depicted in fig-3. Pressing the START button causes the app to display a screen similar to figure 4, which impart the necessary crop details, including crop selection, irrigation method, soil type, and soil test data status.

**Table 2: Fertilizer recommendation**

Reco-I	Urea	SSP	MoP
Reco-II	DAP	Urea	MoP
Rec-III	NPK (18:18:18)	Urea	MoP



**Fig. 3: Main Menu**



**Fig. 4: Essential Details**

The Fertilcal-P App comes up with two modes for estimating the amount of fertilizer needed. If the soil test report is available, the next screen switches to the page where the user can enter the values of N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O, and pH from soil test data, as shown

in Fig.5 otherwise the app shows the fertilizer recommendation in KgHa<sup>-1</sup> as per the standard agronomic ratios amended by the government for N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O chemical fertilizer (Fig. 8).

The Fertilizer-P App provides two options for estimating the amount of fertilizer needed. If the soil test report is available, the next screen switches to

the page where the user can enter the values of N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O, and pH from soil test data (Fig. 5).

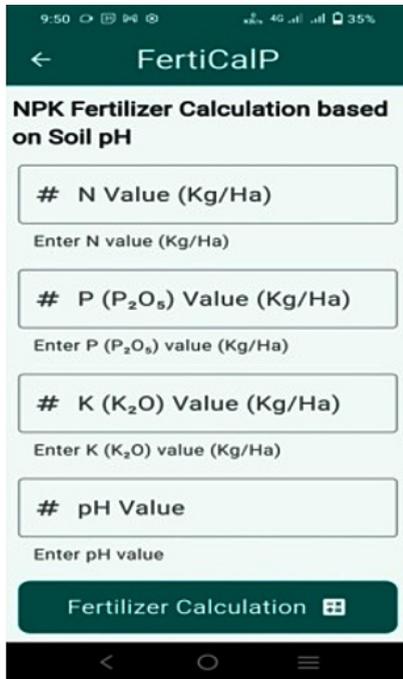


Fig. 5: To enter soil Test Data

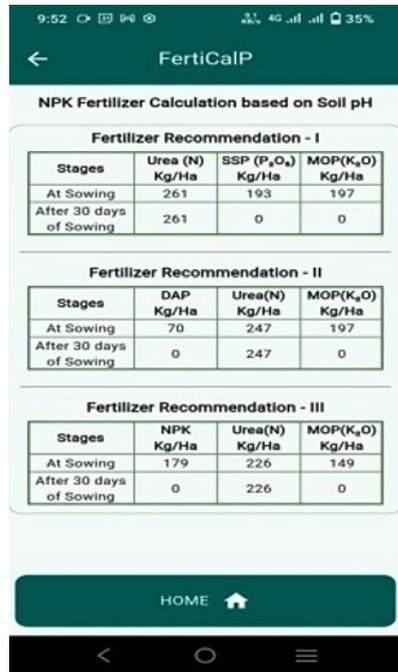


Fig. 6: NPK Recommendations

When pressing the Fertilizer Calculation button, the app will calculate three fertilization recommendations Fig.6. As illustrated in Fig.7, the pricing breakdown

button, which allows the farmer to choose the most cost-effective fertilizer recommendation.



Fig. 7: Price breakup screen

Process Breakdown

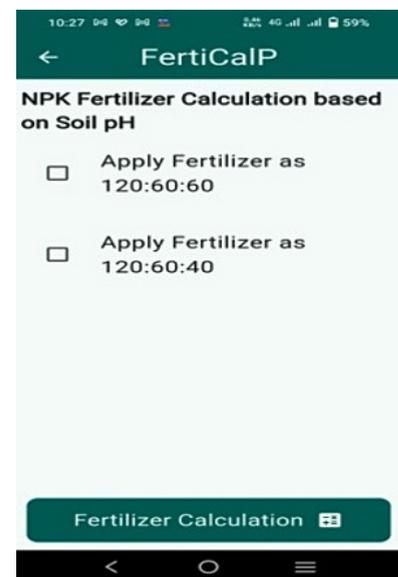
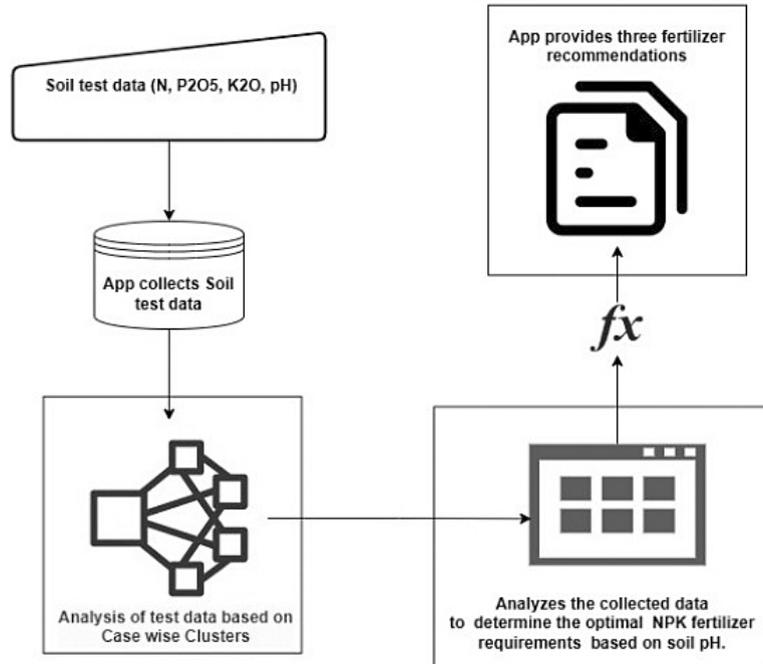


Fig. 8: Standard agronomic recommendation

**Data Acquisition**

Before acquiring the soil test data, the user can configure the app by providing the necessary crop details, including crop selection, irrigation method, soil type, and soil test data status. The

system collects soil test data that includes essential parameters such as N, P<sub>2</sub>O<sub>5</sub>, (K<sub>2</sub>O), and pH levels. These data are stored in a centralized application for further processing. Fig-9.



**Fig. 9: Operational Flow of Software**

**Data Clustering**

We analyze the collected soil data using case-wise clustering. This step involves grouping similar data points using clustering algorithms to identify patterns and trends in the soil's nutrient composition.

**NPK Requirement Calculation**

After clustering, the system performs an analysis to determine the optimal NPK fertilizer requirements. This step factors in the pH levels to fine-tune the NPK ratio for each cluster, ensuring balanced soil nutrient management.

**Fertilizer Recommendation Generation**

The application then computes and provides three fertilizer recommendations based on the analysis results. These recommendations are tailored to optimize crop yield and maintain soil health based on the specific characteristics of the soil cluster.

This app compares the price breakdown on the last screen and provides recommendations based on the need for NPK fertilizer.

**Technical features**

Clustering Algorithm utilizes Fuzzy clustering an association with machine learning technique for case wise data clustering. Fuzzy clustering offers overlapping flexibility, robustness, and interpretability.

Data Processing The integration of soil parameters with pH level considerations ensures precision in the recommendation output.

Recommendation Engine The application deploys a recommendation engine to output three potential fertilizer solutions that align with the soil's nutrient profile.

After the coding phase, the testing phase is performed by connecting the database to the developed modules with Open Database Connectivity (ODBC). Debugging is performed to correct the syntax and semantic errors in the developed program. Finally, a 'setup' program was prepared for easy loading and execution of the software.

## Result

### If Soil Test is YES

The FertiCal-P App schedules the recommendation of NPK fertilizers in two stages, the first at sowing and the second after 30 days of sowing, ensuring optimal fertilizer efficiency, reduced fertilizer usage, fewer expenses and ultimately adverse impact on environment. The app is developed using rule based and regression techniques and it calculate three different fertilizers recommendations with costing.

### Recommendation-I

tell us the requirements of urea, SSP and MoP according to soil test data.

### Recommendation-II

for DAP urea and MoP.

### Recommendation-III

for triple NPK (18:18:18), urea and MoP of chemical fertilizer kg per hectare.

At last, farmers select the price breakdown button to ascertain their fertilizer needs by analyzing the cost analysis displayed on the app's final screen, rendering it the most versatile option.

### If Soil Test is NO

If a soil test is not available, the app shows the fertilizer recommendation in Kg Ha<sup>-1</sup> as per the standard agronomic ratios amended by the government for N:P:K fertilizer. Consequently, it fulfills its purpose by providing cost-effective decision support to the stake holder.

## Discussion

The FertiCal-P App works well within the ranges and values specified in the table-1 for soil test data. If the soil test data beyond the mentioned band then app could not accept the inputs for N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O and pH. Before applying this strategy throughout the Indian

subcontinent, we will test it first at the district level in Gujarat. Once the farmer complies with the app's recommendations for chemical fertilizer, the end user will undoubtedly reap financial rewards.

## Conclusion

The present study the Fertical-P app application accomplishes the primary objective of precision agriculture, to obtain greater fertilizer efficiency with minimum inputs for sustainable agriculture. The Fertical-P App provides decision support for technology-based engagement in agricultural decision-making. Further test are needed at the district level in Gujarat before implementing it across the entire Indian sub-continent. With this app, the farmer, can make financially and agronomically beneficial decisions by referring to the statistics provided in the app's final screen.

## Future Scope

The Fertical-P App has the potential to expand its functionality by incorporating fuzzy rules for cotton and rice crops into the crop selection menu. Offering a selection of multiple soil characteristics, such as black and sandy, and providing the option to update irrigation types by adding rain fed, can further enhance the Fertical-P app's functionality. Thus, the aforementioned app provides coverage for nearly three major crops in the state and enhances its operational popularity in the farmer community.

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## Conflict of Interest

The authors do not have any conflict of interest

## Data Availability Statement

The manuscript incorporates all datasets produced or examined throughout this research study.

**Ethics Statement**

This research did not involve human participants, animal subjects, or any material that requires ethical approval.

**Author Contributions**

- **Mukesh kumar Sharma:** Author engaged in conceptualization, methodology, and the composition of the original draft.

- **Manoj Khediya:** Precision Agriculture concept, Writing and & Editing the draft.
- **Dr. Chetan Bhatt:** Offer comprehensive oversight and aid in the resolution of intricate instances as needed.

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