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ANALYSIS OF NUTRIENT CONTENT IN THE SOIL USING ISFET VIA GSM FOR AGRICULTURAL DEVELOPMENT IN RURAL INDIA

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Abstract— **On the analysis of the characteristics of current agricultural scenario in Rural India,we put forward the concept ofa faster andmore efficient solution for soil sampling by the use of Global System of Mobile communication(GSM) for accurate fertilizer recommendation. In this paper, an overview of the challenges faced by the Indian farmers in increasing crop productivity is shown. The working of integrated ISFET(Ion sensitive Field Effect sensorfor measurement of ion concentration (H^+, NO_3^-, Na^+, Ca^{2+},K^+) in the soil is discussed. It is followed by the implementation of electronic prototyping tool, Arduino for interfacing the sensor with the cellular phone along with a brief analysis of GSM connectivity in remote villages. The GSM acts as a mechanism in bridging the gap between the farmer and the Soil testing Laboratory. A case study on the village,VelliangattuPudhur, Erode district, Tamil Nadu has been presented.**

***Index Terms— Soil sampling, crop productivity, Global System of Mobile communication, ISFET, Arduino*.**

I. INTRODUCTION

Although developments in industry, trade, commerce and stock market have been making the headlines as the indicators of India's economic growth; agriculture still continues as India's economic foundation. This is precisely because of the fact that the country's sustainable growth in Gross Domestic Product (GDP) will depend upon the sustainable development of agriculture, which employs more than 60% of India's population.

The agricultural development, however, has failed to maintain its sustained growth. Although the country has the highest irrigable land size ratio in the world; is one of the world's largest producers of farm commodities; and has vast diversity; paradoxically the country still has more than 250 million underfed people, below the poverty line and has high under-employment issues.

Sustained, although much slower, agricultural growth in the 1990s reduced rural poverty to 26.3 percent by 1999/00.Since then, however, the slowdown in agricultural growth has become a major cause for concern. India's rice yields are one-third of China's and about half of those in Vietnam and Indonesia. With the exception of sugarcane, potato and tea, the same is true for most other agricultural commodities.

Besides taking steps such as greater public investments in agriculture; enhancing investments in rural infrastructure, particularly in rural roads and electrification; improving water management, strengthening the agriculture marketing and processing of agricultural commodities to name a few, a real initiative has to be taken to make the farmer aware of the quality of his land, which can only be achieved by soil sampling.

The multiple nutrients essential for crop production include Nitrogen, Phosphorus, Potassium, Sulphur, Hydrogen etc. There are not always enough of these nutrients in the soil for a plant to grow healthily.

Careful soil sampling is essential for an accurate fertilizer recommendation. A sample must reflect the overall fertility of the field so an analysis accurately represents the nutrient or mineral status of the soil. An accurate evaluation will result in more efficient fertilizer use which will cause an exponentially increase in the crop yield and reduce cost and environmental damage, which is our motive.

II. ION SENSITIVE FIELD EFFECT TRANSISTOR SENSOR

Standard methods to measure nutrient levels in soil are complex and time consuming due to the extraction and pre-treatment processes involved. Theinstrumentation used for these measurements is also expensive. Therefore, the use of chemical sensors would be efficient since they can be applied directly to the soil. Thus, it would provide results in real time at a moderate cost. In this work, the use of chemical sensors based on Ion Sensitive Field Effect Transistors (ISFETs) for soil analysis is proposed. These devices are fabricated with microelectronic technology -providing this fact some important advantages-

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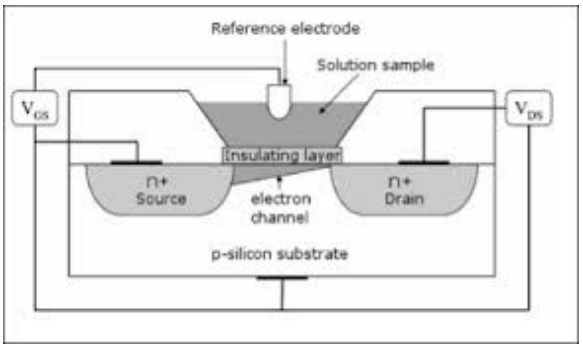

Fig.1 Basic functional diagram of ISFET

[1] An ISFET is an ion-sensitive FET used for measuring ion concentrations in solution and in this study, it is used to estimate the ionic concentration of nutrients present in the soil sample when added with distilled water. When the ion concentration (such as H^+) changes, the current through the transistor will change accordingly. A voltage between substrate and oxide surfaces arises due to an ions sheath.
Most ion sensors are potentiometric sensors, which means that the electrical potential
difference, $\Delta\phi$, at a solid/liquid interface as function of the ion concentration to be
determinedis measured. This is always according the Nernst equation:

$\Delta\phi = RT/F \ln ai1/ai2$

Here R is the gas constant, T the absolute temperature (K) and F the Faraday constant.
The sensitivity RT/F is the same factor as kT/q as known from solid state physics.

Highly selective organic membranes for different ion-concentration measurements such as K+, Ca2+, Mg2+ are deposited and structured with a wafer-scale photolithographic technique. Due to the very good adhesion and stability of these membranes, the specific ion selective FET can be used for ion-concentration monitoring with a good sensitivity and a linearity within a wide range of concentration down to $10^{\wedge -6}$ M.

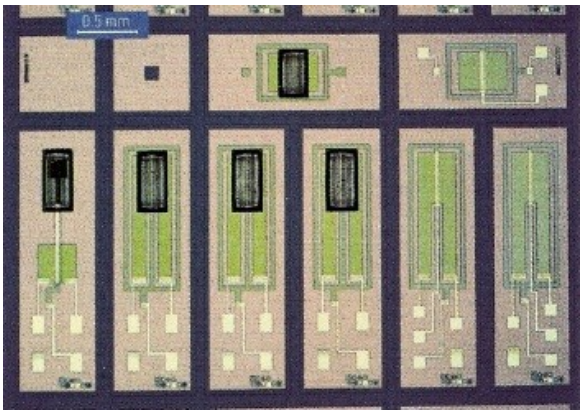

Fig 2.Integrated multiple ion sensitive FET

III. ARDUINO INTERFACE

[3] A data transfer mechanism is proposed to achieve an efficient and cost effective transmission of the chemical data to the laboratory.
By implementing an Arduino-sensor unit, an Arduino program has been executed to read the analog output of the chemical sensor (in this case, the ISFET electrode) and use it as an input so as to send a text message automatically to the contact number of the correspondent at the test centre, using the farmer's cellular phone and existing cellphone towers.
The connectivity and data transfer rate will depend entirely on the number of cellular towers in the
village thereby using existing resources for multiple applications.

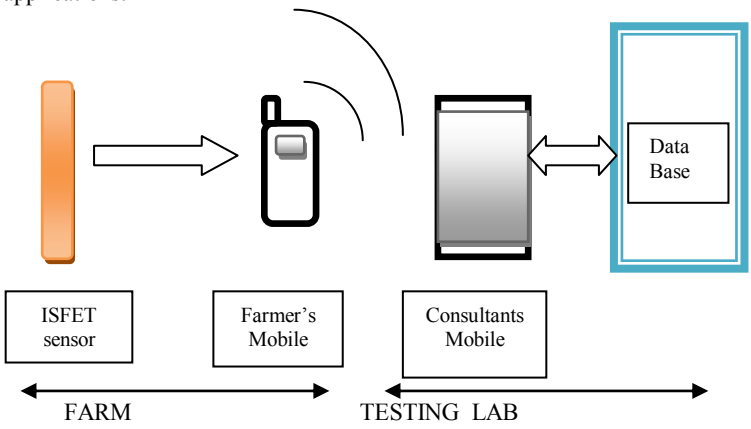

Fig 3. Block diagram of proposed model

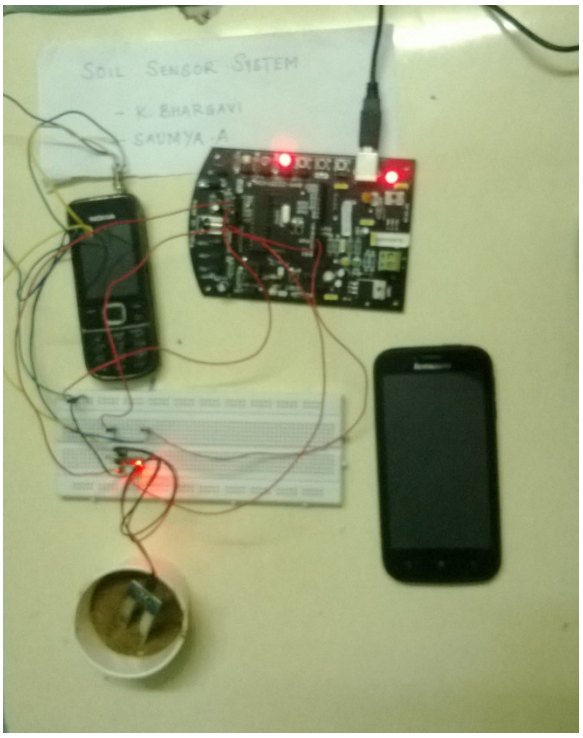

Fig 4.Working Model

In order to establish automatic hassle-free transmission of chemical data from the agricultural
farm to the soil testing laboratory, certain factors have been taken into consideration[2]. These include

- Feasibility of Resources
- Accuracy of Data Transmission
- Cost Reduction
- Higher data transfer rate
- Ease of technology

Highlighting the mentioned factors with regard to current technology and future prospects, the demerits of the current soil testing mechanism that have been overcome by our proposal are:

- Generally the time taken in obtaining the soil analysis and fertility recommendations is as long as 3-4weeks and can be extended up to 6-8 weeks during rush seasons.
- The cost of testing a single sample of soil for rice growth, which is the staple food in South India, especially in the rural areas is Rs.250/sample according to Agritech,India. Assuming the farmer samples his land four times a year, for four seasons every three months, the net cost would be more than Rs.1000/- including transport charges.
- The testing process at the laboratory is a tedious process that requires skilled personnel in the chemical field to analyse the given sample.

Our proposed idea aims to achieve the following keeping in mind the factors as mentioned

- A few minutesis all that is required to obtain a chemical result from the sensor. Its “on-the-spot” capability is a key advantage.
  The fertilizer recommendation report during rush seasons takes a maximum of one day.
- Any chemical sensor used to obtain nutrient content(in this case, ISFET) is of low cost and would be a one-time investment. The charges of testing and travel can be avoided around the year.
- Since, the database in use is fed to the system and requires no prior knowledge on the usage of internet,minimum training needs to be given. We aim to increase employment opportunities among the rural women by extending correspondent jobs to Self Help Groups(SHGs) of women in rural areas.
- Only existing resources have been employed to execute the task. The use of GSM is an added advantage due to the wide range of cellular towers. A cellular phone network touches almost every corner of rural India today, hence avoiding the unnecessary cost in setting up new connection methodologies.
- No use of internet required throughout the samplingprocess.

IV. CASE STUDY: VELLIANGATTU PUDHUR

VelliangattuPudhur (also known as KuravanPalayam) is a small and remote village in Tamil Nadu, India, in the Gobichettipalayam taluk, Erodedistrict. It has a population of 125. Males constitute 51% of the population and females 49%.Agriculture is the primary occupation, with rice,coconuts, turmeric, bananas and sugarcane being the main crops grown, rice being the staple food. There are about 27 farmers residing here.
The village has dry weather throughout the year except during the monsoons. The types of soil present are Red Sandy and Red loam variety.The nearest test centre for soil sampling is the “Soil Testing Laboratory”,41/74,PongundranarStreet,Karungalpalayalm, Erode which is at a distance of 36kms from the village.
The distance of the testing laboratory from a farmer, the cost in testing and the time in obtaining reports are all hindrances in the procurement of efficient crop yield. These limitations can be overcome by the implementation of the ISFET kit.

The macronutrients for the crops mentioned above are Potassium, Phosphate, Nitrate along with other micronutrients.The various steps involved in the soil sampling process include:

Nutrient (kg/ha) / Crop	Nitrate	Phosphate	Potassium
Rice	218	31	258
Coconut	49	23	115
Turmeric	187	39	327
Banana	1	0.25	2.25
Sugarcane	83	372	168

Table1 [4]: Database of macronutrients for VelliangattuPudhur village

STEP 1: The farmer places the ISFET electrode into the soil added with distilled water and switches it onfor a period of one minute. The soil layer should be at a depth of 6-7 inches from which the soil is tested.
STEP 2: The ISFET electrode sends an electrical analog signal to the Arduino interface which sends a text message via the farmer's cellular phone automatically at the end of two minutes to a correspondent at the soil testing laboratory.
STEP 3: The correspondent analyses the data by comparing it with the database provided to him/her at the soil testing laboratory.
The following values of nutrients need to be added in order to produce 9.8t/ha of grain in 115 days uptake.

STEP 4: The correspondent decides on the optimum fertilizer required to enhance the soil quality and sends this information back to the farmer via text message.

Hence, in four easy steps the soil testing procedure is completed and the farmer can now improve the soil fertility of his farm at low cost and within less time.

V. CONCLUSION

An effective solution to the difficulties in the current soil sampling techniques has been implemented by programming the Arduino interface. A working module of the sensor-mobile interface has been created. By using the existing GSM technology, we have focused on the overall development of Rural India, both in terms of agriculture and employment opportunities among the rural population. Area for further improvements is error reduction in sensor.

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