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MOISTURE INFLUENCING SOIL CROPS DATA USING SENSOR ARDUINO INTERFACE & MACHINE LEARNING APPROACH

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Abstract
Growth and yield of any crop is closely related to availability of nutrient in the soil. However, the availability of nutrients has intricate relation with the level of soil moisture. Nutrients uptake for plant has positive correlation with solubility of these nutrients. The solubility of these nutrients itself depends on the level of soil moisture. When adequate amount of soil moisture is available, nutrients solubility improves. Conversely, low level of moisture in the soils reduces the availability of nutrients. Understanding this convoluted relation of soil moisture with nutrient solubility is of paramount importance to enhance the crop yield and quality. In this research work, moisture in the soil is measured and its impact is evaluated and studied. Research database comprises of 10 crops with 10000 samples from each crop. There are 9 parameters in each sample. Nutrient levels are further assessed through pattern recognition, achieving recognition accuracy of up to 95.64%. Also sample data has been recognized with ANN using backpropagation algorithm with an accuracy of 82% and Specificity of 94.89%. MATLAB, Arduino Uno and soil moisture sensor DHT11 are used.

Introduction
Traditional knowledge in agriculture is important but is not sufficient for mitigating challenges of this era like climate change, limited resources, ever growing food demand etc. Data driven techniques can help in making key changes to enhance the crop yield and quality on one hand, while optimizing the use of limited resources on the other. Data used in the work has been obtained from the Kaggle website [1]. Existing information from soil surveys does not often meet data requirements for modeling or prediction [2]. Crop growth generally depends on macronutrient and micronutrient content of soil, which again is parametric representation of different climatic condition like rain, humidity, temperature, sunlight and contents of soil [3]. Agriculture is an important occupation world over, which has dependency on multitude of factors like temperature, soil moisture, availability of nutrients and many other factors.
Effective water management may increase nutrients availability which helps in improving crop yield and quality. Mineralization is essentially related to level of soil moisture and effective water management helps in the transformation of soil nutrients. It has been found that water deficit causes water stress in plants, inhibits root growth and reduces root absorbing area whereas excess water causes nitrogen leaching and reduces nitrogen recovery. So soil moisture level should be optimum which will enhance crop produce and quality. [4]
Knowledge about a crop, season of crop, nutrients in the soil, atmospheric conditions are being studied by the farmers in a conventional and traditional manner. A particular crop might yield better throughput in a particular environmental condition. Governments encourage such activities through its universities and research institutes. Technology and industry sector also help in developing new techniques for enhancement in the field. With the advent of internet, data from different sources can be analyzed and processed. New models and techniques might help in data analysis. In this work statistical approach is being applied for data analysis.
A comprehensive analysis of the variables and parameters can provide information to draw conclusions about crops and help farmers to take informed decisions. The parameters in this study are urea (nitrogen), pH, Soil EC, phosphorus, potassium, T.S.P, M.O.P, temperature and soil moisture, as discussed below:

1.1 Nitrogen

Nitrogen (N) is an important constituent of soil and essential in the production and transformation of soil organic matter. Nitrogen decides the soil's physiochemical and biological properties. Nitrogen is available in sedimentary rocks is not available for plants. Nitrogen released during soil organic matter decomposition influences amount of Nitrogen consumed by soil micro organism and thereafter mineralization rate. [5] Nitrogen boosts the growth of crops. Deposition of Nitrogen has increased due to industrial revolution and anthropogenic activities. Nitrogen use efficiency is affected by various factors like plant age, plant characteristics, behavior of soil and climatic factors. The extent of nitrogen utilization by plants also depends on the stage of the plant growth. During the stage of germination and seed development plant has short root and lesser number of leaves so, supplying larger nitrogen than the extent to which it can be used by the plant will result in wastage of resources. Nitrogen utilization will increase as the plant grows in size, its roots are developed and leaves become wider. Eventually, when the plant move towards completion of life its nitrogen utilization efficiency again reduces so the supply of nitrogen should also be reduced in accordance, to avoid the wastage of resources [6]. Nitrogen supply also affects amino acid composition of protein and its nutritional quality. In case of cereals the excess supply of nitrogen reduces the relative portion of lysine and threonine thus reducing the biological value of protein. In case of oil crops, the effect of nitrogen fertilization on oil composition and quality are inconsistent, upon nitrogen fertilization the protein levels are increased, whereas oil concentration reduces.

In sugar beet production, excess supply of nitrogen causes reduction of sucrose concentration per unit fresh matter and raising the level of impurities (alpha-amino-nitrogen, invert sugars, and lime salts), diminishing the efficiency of sucrose extraction. In case of potato, nitrogen supply affects various characteristics like tuber size, dry matter and sugar contents thus by managing the supply of nitrogen the desired parameters can be obtained, like in case of French fries and potato chips. [7]

Although, globally nitrogen is the most widely used fertilizer nutrient, it has been found that only 50 % nitrogen is used effectively by the crops where as remaining 50 % is lost to the surroundings, this not only results in the financial losses to the farmers but also causes water, soil and air pollution. So, enhancing the nitrogen utilization efficiency is critical through proper management practices not only for the farmer but also for global needs to protect environment. [8] It has been found that, in the last six decades the use of reactive nitrogen as fertilizer has grown rapidly, on the other hand the nitrogen use efficiency has been reducing, which results in the leakage of nitrogen in the environment. Furthermore, it has been estimated that fertilizer consumption in India may double by year 2050, raising the need for scientific research for better nitrogen management practices in Indian agriculture. Experts from the UK and India came together for a conference and workshop on "Challenges and Opportunities for Agricultural Nitrogen Science in India. The meeting resulted in three important guidelines: (1) Soil stewardship is essential and legumes need to be planted in rotation with cereals to increase nitrogen fixation in areas of limited Nitrogen availability. Synthetic symbioses and plastidic nitrogen fixation are possibly disruptive technologies, but their potential and implications must be considered. (2) Genetic diversity of crops and new technologies need to be shared and exploited to reduce nitrogen losses and support productive, sustainable agriculture livelihoods. (3) The use of leaf color sensing shows great potential to reduce nitrogen fertilizer use by 10–15%. In addition to this the use of neem coated urea and the application of manure, urine and crop residue can result in improvement of nitrogen usage efficiency in India by 20-25%.[9] Yousaf, M. et al., investigated the effect of nitrogen and fertilizer on radish. Nitrogen and magnesium were applied at different rates. In this experiment various parameters like growth, yield and quality indicators of radish (plant height, root length, shoot length, plant weight, total soluble sugar, ascorbic acid, total soluble protein, crude fiber, etc.) were studied and it was found that different rates of nitrogen and magnesium affected all this parameters and radish quality. In contrast, the crude fiber contents in radish decreased significantly with increasing nitrogen and magnesium level. [10]

Every crop exhibits distinct effects in response to nitrogen fertilization. In oil-seed nitrogen enhances the protein content but deteriorates the oil content. In case of fruits, nitrogen effects various parameters such as size, shape, color, texture, flavor and composition also excess supply of nitrogen results in reduction in quality of crops and also effects environment, so key plant parameters are to be monitored minutely to find out the optimum value of nitrogen fertilizer. [11]

1.2 Phosphorous

Phosphorous (P) is an essential nutrient, playing a key role in plant development and growth Hence, ascertaining the way in which phosphorus participates in the physiological responses of plants to abiotic stresses is essential to ensure the sustainability of agricultural production systems.[12]

Phosphorous containing compounds play crucial role in energy metabolism including membranes, structural support (teeth, bones), genetic components (DNA, RNA) and the photosynthesis process (for plants). Nearly everywhere in the world phosphorous acts as growth limiting factor due to its low concentration in soil and high solubility.[13]

Like nitrogen, phosphorous too can have adverse affects on environment if it is used beyond optimum level. For the past four decades in many European and North American countries have over used phosphorous, on the other hand in many parts of world, notably in the African countries the crop yield has been constrained due to low availability of phosphorous. Rock phosphate is the key raw material for phosphate fertilizer. However, these resources need to be used judiciously, owing to the fact that these are limited in quantity. [14]

Part of applied Phosphorous is accumulated in the soil in non-labile forms due to its chemical high-affinity reactions and occlusion to soil minerals and organic matter, known as "legacy P. Availability of phosphorous fertilizers beyond plant requirements leads to build up of legacy P in soils. Unfortunately, this imbalanced P input to output ratio is necessary in most cases to maintain satisfactory yields in conventional agricultural systems but it leads to environmental concerns like eutoriphication, if it is transferred to water bodies. Considering the fact that it is difficult to economically renew the phosphate, agricultural practices need to be aligned in manner so as to provide for appropriate use of phosphorous.[15] Crops require adequate supply of phosphorous during the earlier stage of growth, thus it is important to provide it in ample amount during the plantation stage. Extensive soil testing is required to avoid excessive usage of phosphorous to prevent wastage of resources and also environment degradation. [16] From the fertilizers, phosphorous residue irreversibly enters the soil, this build up of plant available p is called as Olsen and it has been found out that there is strong relationship between Olsen P and crop yield. The critical level of Olsen P, is the level at which soils should be maintained to optimise P-use efficiency.[17]

Phosphorous in soil also negatively affected by the nitrogen deposition and increased precipitation. [18] K_2O: Potassium oxide is used as glass flux to decrease the working temperature. [19] Phosphorous (P) rich bone char (BC) is an alternative P fertilizer in agriculture. When sulphur concentration increases from 1% to 27% and pH decreases from 8.6 to 5, p solubility in water, neutral ammonium citrate and citric acid remains unchanged. [20]. Eutrophication of water bodies with high share of agriculture land and catchments is common. Phosphorous shows a limiting factor in most fresh waters. Significance of phosphorous lies in its dominant role in the eutrophication in aquatic ecosystems. Water quality rises with control of eutrophication and management of phosphorous losses from agriculture.[21] Reduced autumn tillage is an effective way to mitigate in case of soil erosion and in total phosphorous losses. [22]

1.3 Potassium

Plants require Potassium (K) and magnesium (Mg) in large quantities. Both these elements play key role in the photosynthesis process and the subsequent long-distance transport of photoassimilates. If K is not present in sufficient quantities in photosynthetic tissues, complex interactions of anatomical, physiological and biochemical responses result in a reduction of photosynthetic carbon assimilation. [23] Due to complex soil dynamics which are affected by root soil interactions, the availability of potassium is highly variable. At plant tissue level, potassium is second to nitrogen with ranges of 1 to 3% by weight. Therefore it is second only to nitrogen in importance of plant growth. [24] The importance of potassium has been ignored for a long time in history but it has been found out that it plays a key role in processes related to plant growth, metabolic functions, stress tolerance, development of root system architecture and cellular functions. Thus it plays vital role in plant growth, consequently it is important to study the effect of potassium on plant growth parameters.[25]

1.4 Soil Moisture

The world's urban population is growing rapidly due to various reasons. The rural-to-urban migration has become a cause of concern not only for developing countries but also for many developed countries. Children of farmers do not want to continue farming because agriculture is gradually becoming less desirable as they are unable to return the money they borrow for buying farming inputs (e.g., seeds, insecticides, fertilizers etc.) after their crops fail or do not yield enough, for example, due to natural calamities such as drought or floods.

Cereal crops including rice, wheat and various pulses are the major crops grown in India. Their production rely heavily on the climatic conditions and therefore variability in the seasonal climatic conditions can hamper the crop yield particularly during droughts in which soil moisture reduces to its minimum value. Thus it is important to predict crop productivity in different climate conditions for developing better techniques which can accurately predict the effect of change in climatic conditions so that farmers and stakeholders can adapt to these conditions and can have better crop selection. Increasing world population and changing climatic conditions has put pressure on the arable land. The availability of information related to climatic conditions, fertilizers and effect of various nutrients, can assist farmers to make the best decision for their cropping situations. This could benefit them in attaining higher crop productivity if the conditions are suitable or help them to reduce the losses if conditions are unsuitable for the crop yield. [26]

In recent times the frequency of extreme events has increased, such as the occurrence of high temperatures, frequent flooding in some areas and droughts in other areas, resulting in detrimental effects on crop yields especially. Due to change in global climate these factors are expected to deteriorate progressively over time. Such changes can deeply affect the crop yields across the world and as such pose greater challenges for not only for farmers but the whole world. [27]

In case of paddy crop, during the vegetation period, increase in temperature increases the yield whereas the rainfall does not influence the yield but this may be consequence of availability of irrigation facilities in the area under the study. However, during the reproductive phase both temperature and rainfall do not affect the paddy yield. During the grain filling and maturation phase paddy yield could be expected to be better at lower temperatures and deteriorate at higher temperatures. Paddy yield is also found to be negatively correlated with the rainfall, showing decline during high rainfall and improvement in yield during the periods of low rainfall. [28]

Ever-growing rise in population of the world has resulted in rise in the demand for food and it is essential to elevate productivity of the limited cultivable land to meet the rising demand for food. This can be achieved in by employing modern techniques which measure the important parameters related to crop specially the soil moisture. Availability of the information about the soil moisture helps the farmer to manage the irrigation facilities more efficiently. This will not only enable the farmer to optimise the amount of water to be used for irrigation but also enhance the crop yield. [29]

Crops plantation dates are considered one of the most important factors in the success of crops plantation process. Obviously, each crop needs suitable values of climate variables to be planted in a certain soil. Every type of soil has a range of suitable values of climate variables to ensure a productive and profitable plantation process for a specific crop. Unfortunately, the ongoing changes in climate variables affect the suitability of planting most crops in the same soil at the same traditional dates. So, such changes in climate variables like temperature and humidity make the traditional plantation dates of some crops in a given place unsuitable. [30]

1.5 EC Value

Soil electrical conductivity (EC) measures the amount of salt present in the soil. Various parameters like crop yield, plant nutrient availability and activity of soil microbes are affected by soil electrical conductivity. The main sources of soluble salts are irrigation water and fertilizers added to the soil. Soil EC value plays an important role. It should always be an optimum value, too high or too low high value reduces the crop yield. Too high EC value causes reverse osmosis, drying up the roots where as too low value indicates low availability of soil nutrients. Based on fertilizer requirements and growth stage

different crops have different optimum values of EC value. The optimal EC value for plant growth is usually between 0.8-1.8, and should not exceed 2.5.
Soil environment plays an important role in determining the crop yield and quality. Soil EC value indicates the concentration of ion in the soil and this is also indicator of soil health. The soil EC value is strongly related to crop yield, level of plant nutrients and activity of soil micro organisms. A low EC value reduces the crop yield, even its high value reduces the crop yield due to soil damage. Thus Soil-EC value should be optimum. [31]

1.6 Temperature

Temperature is one of the most crucial factors in the growth and yield of the crops. Warmer temperature due to global warming will affect crops yield. In case of maize warmer temperature during the reproductive periods reduces the yield by 80-90%. The expected changes in temperature over the next 30-50 years are predicted to be in the range of 2 to 3°C. Events of extreme temperature are expected to be more frequent and severe in the coming years compared to current era. This will have greater impact during the summer period. Temperature also reduces the fruit production due to reduction in the process of pollination. [32]
Every crop has different value of threshold temperature, in case of rice crops this threshold temperature is 35 °C. According to Food and Agriculture Organization (FAO) data, there has been reduction in rate of increase in cereal crop yield, whereas the yield should increase by 70% to cope up with rising population. A 2 °C rise in temperature can reduce the cereal grain yield by 20-40%. High temperature during grain-filling has a significant effect on sunflower seeds and oil constituents. In addition, it also reduces the linoleic acid content in numerous oilseed oils. [33]

Hardware Used

2.1 Arduino Uno: Arduino Uno is one of the most popular used microcontrollers used in the realm of electronics, programming and embedded systems. Arduino Uno is popular due its affordability, versatility and ease of use. Its key features are:
2.1.1 Microcontroller: At the heart of the Arduino Uno is the ATmega328 microcontroller, a powerful chip that handles all the processing for the board. It operates at a clock frequency of 16 MHz. It has 32 KB of flash memory for storing programs, 2 KB of SRAM for runtime data, and 1 KB of EEPROM for non-volatile data storage.
2.1.2 Power Supply: It operates at level of 5 volts, it uses a voltage regulator to step down the voltage to a safe level.
2.1.3 Digital and Analog Pins: Arduino Uno has a total of 20 I/O pins out of which 14 are digital I/O pins and 6 are analog input pins. The digital pins can be used for tasks like reading sensor data or controlling LEDs, motors, and other devices and 6 analog pins can be used for reading analog signals like output of temperature sensor, these have resolution of 10 bits, these pins can also be used as PWM pins for tasks like controlling motor speed.
2.1.4 Communication: The Arduino Uno can communicate with external devices using these three group of pins: Serial Communication: it has two serial communication pins 0 (RX) and 1 (TX). These pins are used for communication between the Arduino and a computer or other serial devices. SPI (Serial Peripheral Interface): These pins are used to communicate with peripheral devices like sensors, memory or even other microcontrollers. I2C (Inter-Integrated Circuit): The I2C protocol helps in communicating with devices like real-time clocks, EEPROMs, and other microcontrollers.
2.1.5 USB Interface: It has a USB-B port which enables it to connect to a computer for programming and power.
2.1.6 Pin out of Arduino Uno: Digital Pins (0-13): These are used as input pins for reading digital signals and as output pins for driving devices like LEDs and relays.PWM Pins (3, 5, 6, 9, 10, 11): These are digital PWM output pins for controlling devices like motors and dimming of LEDs. Analog Input Pins (A0-A5): These are 10 bit analog pins working with sensors like temperature or light sensors. Power Pins: 5V Pin: This Pin provides 5V output to power external components, 3.3V Pin: This pin

provides 3.3V for devices that require lower voltage. GND Pins: Ground pin is for completing electrical circuits. V_{in} Pin: This pin is used for supplying external power supply to the board.

2.2 Soil Moisture Sensor

Fig 1: DHT11 Sensor

Figure 1 shows soil moisture sensor. Soil moisture sensor is used for assessing the level of moisture in the soil. So it is widely used in the agricultural applications for efficient use of irrigation resources. This module consists of two key components:

2.1.1 Probes (sensor): It has two metal probes that are dipped in the soil. It works on the principal of electric conductivity between the plates. In case of dry soil, conductivity is less due to limited availability of water molecules whereas, conductivity increases in case of wet soil.

2.1.2 Control board: Pc and Arduino interface acts as a data controlling, monitoring and recording unit. Arduino has 28 pins. A1 analog pin is used to read sensor data. TX (Serial pin 1) pin is used to capture data and put it up on the PC screen.

2.2 Working Principle of Soil Moisture Sensor

Soil moisture sensor comprises of two metallic strips that are dipped into moist soil. The dipped strips work on the principle of electrical conductivity between the strips. Moisture content in the soil dictates the conductivity. The electrical conductivity is captured by A1 pin of Arduino and finally displayed on the PC.

Methodology

In this experimental study, research data of soil parameters is downloaded from research data base.[1] Data comprises of ten types of crops namely carrot, chilli, cinnamon, corn, eggplant, rice, strawberry, sunflower, tomato, wheat. Each type of crop contains 10,000 samples. Moisture data in the database is modified by data acquired from the soil moisture sensor with different moisture content. Data acquired from the sensor lies in the range (0.1% to 1.27%) and (44.67% to 46.77%). The result, indicate that there is significant impact in samples with low moisture content (0.1% to 1.27%).

Moreover to study the variation in various nutrients, an associated memory is used that can map data. An accuracy of 95.64% has been achieved when data is acquired at various nodes.

There are nine parameters in each crop. Out of these parameters, one parameter that is soil moisture is altered for the analysis. New values of the soil moisture are obtained from the soil moisture sensor. Arduino UNO is the key processor used in this study. It works on 5V supply and there is ground pin, Pin A1 captures the soil moisture value. Interface of sensor DHT11 with Arduino is presented in figure 2

Fig 2: DHT11 Sensor Interfaced with Arduino

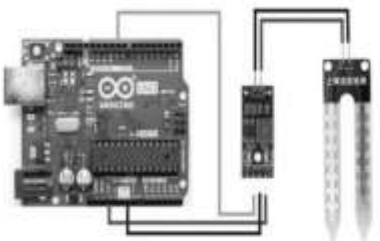


Fig 3: Soil for Experiment at GCET, Jammu campus

Mean deviations and Group mean deviation of Set A- Set B and Set A- Set C are measured with 100 samples and then with 50 samples in each group using Scientific Laboratory. Mean deviation has been found to be significant for carrot, cinnamon, strawberry, rice and tomato whereas it is insignificant for other crops like chilli, corn, eggplant, sunflower and wheat, when sample size is 100. As the sample size reduces to 50, there is no significant difference in any crop for Set B and Set C.

In the second objective, associated memory measured the output with 95.64% accuracy. For this study, 30 samples each from three crops carrot, chilli, and strawberry have been used. The flowchart of this approach is shown in figure 4.

Fig 4: Flow chart for capturing variations using Associated Memory

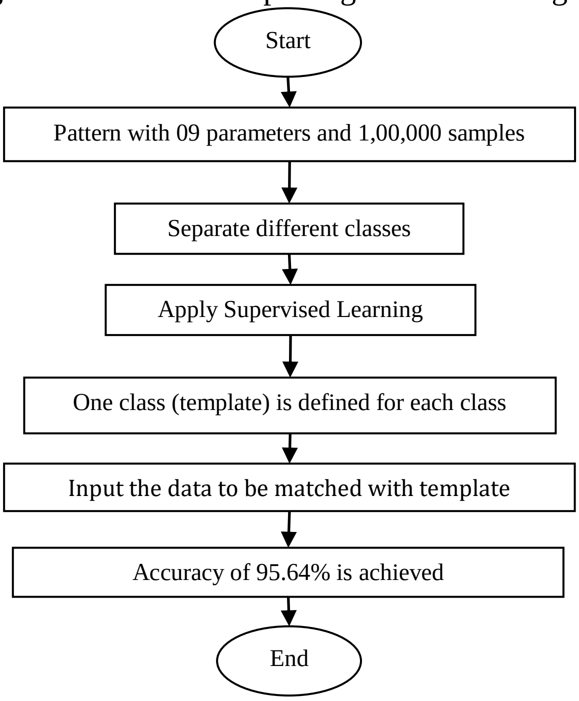
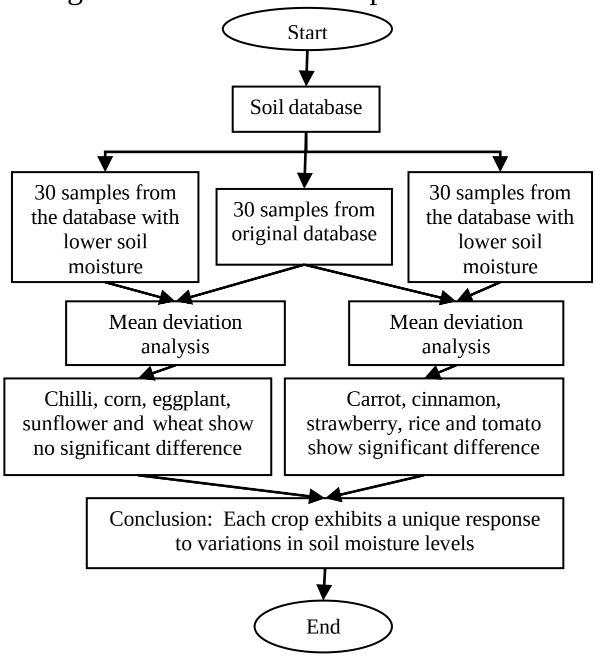


Table 1: No. of patterns recognised

S.No	Name of Crop	Patterns Recognized
1	Carrot	13
2	Chilli	15
3	Strawberry	10

For the third approach, from the given data, 30 samples were taken for each crops from Set A, Set B, Set C and F-Scores were calculated for Set A-Set B and then between Set A-Set C. Flow chart for this procedure is shown in figure 5.

Fig 5: Flow Chart for the process



From the results of this procedure, it is found that, there is significant effect of change in soil moisture level in case of carrot, cinnamon, strawberry, rice and tomato whereas in case of chilli, corn, eggplant, sunflower and wheat, the effect of change in soil moisture is not significant.

Neural network further classifies the data with an accuracy of 82% and specificity of 94.89%.which is comparable to other studies [34].

Conclusion & Future Scope

Water content in the soil has been found to play a significant role in nurturing and development of crops. A proper mix of water and other nutrients helps to improve the crop performance. Other sensors apart from soil moisture sensor can be used in the experiment thus opening the field for many researchers to predict crop soil quality in order to make efficient use of resources and enhancing the crop yield.

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