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An IoT based Tree Specific Soil Nutrient Management System Using Neural Network for Cashew Cultivation

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Abstract— Anacardium occidentale commonly known as Cashew was introduced into India by Portuguese in 16th century. Farmers of Cuddalore District, Tamil Nadu in India, are interested in Cashew Cultivation due to its export market values. To achieve better yield from cashew cultivation, farmers need to supply balanced nutrition to the soil and by following intercropping method. In literature, Recent Technologies like Artificial Intelligence and IOT are widely used to predict dosage of the fertilizer to be applied. By examining the numerous connected ascribe success locations of Cashew orchards, it was possible to determine how much macronutrients like Nitrogen (N), Phosphorus (P), and Potassium (K) were present in the soil and it will be helpful for the understanding of soil fertility level of the area. In our work, using IOT set up which includes Arduino UNO, NPK sensor and OLED display, we identified NPK values of soil for various cashew trees in a particular area. Along with NPK values of soil, inputs include the local soil type, PH and Tree age. Based on the input factors, DL trained model will provide suggestions of fertilizer dose to be applied for a specific tree for the Cashew cultivating farmers for better yield. In our proposed work, LSTM based Recurrent Neural Network (RNN) Algorithm is used to provide a better prediction of fertilizer. With the help of this research, we can be provided with what intercrop to plant and how much fertilizer to use, in what ratio to supply and fertilizer shop suggestion to enhance agricultural knowledge across the globe using the Internet of Things (IoT) and Artificial Intelligence. The result of RNN model was compared with Random Forest, Linear Regression, Linear Random Classifier, Decision Tree Classifier with proving accuracy of 98.7 %. Together with a decrease in the farmers' input efforts, these strategies will increase the productivity of the fields.

Keywords- Cashew, Anacardium occidentale, IoT, Deep Learning, RNN, NPK, Fertilizer Recommendation, Intercrop

I. INTRODUCTION

Indian agriculture continues to be the most predominant sector of Indian economy. As traditional agriculture gives way to modern agriculture, a transitional era is currently underway. The need to protect the world's food resources is essential because of its extraordinarily fertile soil and unpredictable climate changes. Such disasters cause sizable crop production losses, which ultimately harm farmers. A lot of farmers commit suicide because of these losses in income. Inexperience with fertilizer and improper timing of agricultural planting are the main causes of farmer loss of life. Farmers constantly use the same conventional farming techniques without experimenting with new farming techniques utilizing technology, and they apply various fertilizers in arbitrary quantities without knowing the fertilizer's inadequate composition or quantity. Thus, this has a direct impact on crop quality and crop yield. It also makes the soil infertile since different fertilizers are employed as a result of abrupt changes in the weather, which harms the crops.

A. Cashew

During the latter half of the sixteenth century, Cashew (Anacardium occidentale), a Brazilian native, was introduced in India for the purposes of afforestation and soil preservation. One of the best edible crops in the world is the cashew nut. Cashew is an important plantation crop of India. It is generating foreign exchange, creating employment, kernels are a good source of fat, protein, carbohydrates and minerals and vitamins. The internal consumption and export of kernels are increasing year by year. Cashew has grown from its modest beginnings as a crop meant to prevent soil erosion to become the third-largest earner of foreign exchange after tea and coffee. Cashew nut is used significantly in all snack foods. To meet the requirement of processing units, we require around 12 lakh tons of raw cashew nuts. Hence, there is a scope to expand area and productivity. In the western and eastern coastal regions of India, such as Tamil Nadu, Andhra Pradesh, Goa, Karnataka, Kerala, Maharashtra, Orissa, West Bengal, and the northeastern

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hilly states, cashew is grown as a commercial crop. It is anticipated that more cashews will be utilized to create snack bars, a low-calorie option to chocolate bars with lots of calories. It was predicted that the India Cashew Market would expand during the forecast period due to the rising consumption of various snacks and ready-to-eat foods made from cashews in the nation. For many years, people
in the nation have enjoyed eating edible cashews as a snack [5]. They have also been utilized as one of the primary ingredients in desserts and other foods, particularly Asian cuisine.

B. Cashew Cultivation in Tamilnadu

Normally around 200 plants per hectare can be grown. 500 plants/ ha can be planted in a 5 x 4 m high density planting technique using a 225:75:75 kg NPK/ha fertilizer dosage. After five years of planting, fertilizer schedule should be 500:200:300 g NPK/tree each year. TamilNadu cashew varieties [11] are shown in Table 1. Major cashew growing areas of TamilNadu are Cuddalore, Ariyalur, Pudukottai, Tirunelveli, Villupuram, Theni and it is shown in figure 1 and major market areas are Jayankondam, Vridhachalam, Panruti, cashew nut grade includes White/ Pieces, splits, butts, 320,240,180.

C. Management of Soil For Cashew

Cashew is being grown as a neglected crop without any nutritional management. The production can be enhanced by improving productivity in the existing old/new gardens by proper nutrient management as cashew responds very well to the applied manures and fertilizers. Since, it is a perennial crop, unless we provide nutrients externally, there will be depletion in availability of nutrients leading to decline in productivity. Hence, a field experiment was laid out to see the optimum level of nutrient requirement of cashew. In comparison to annual crops, perennials are anticipated to offer higher protection against soil erosion, hold onto more water and nutrients, store more carbon in biomass, and be more pest-resistant (Cox et al., 2006). Even though Cashew is a perennial tree crop it will remove some amount of nutrients from soil regularly. For an average, 30 years tree will intake 2.85 Kg of Nitrogen, 0.75 Kg of Phosphorous and 1.265 Kg of Potassium from soil. If it continues, soil fertility will get worse. In order to balance the soil nutrients ratio, we need to apply manures and fertilizers so that soil fertility maintained and can avoid soil deterioration. However, life cycle assessments (LCAs) of perennial crops are more difficult than those of annual crops since production may not begin for several years and orchards may persist for more than 20 years, making it challenging to collect data for all production stages. Due to this issue, only a few LCAs for perennials have been conducted to date. Cashew growth and yields should be improved at the beginning nursery stage onwards through the use of vigorous plants, dynamic population adjustment techniques, control mechanisms for flowering, sex ratio adjustment, and fruit set/retention, adoption of soil amendment techniques for different soil types, incorporation of cropping system approaches to control weeds, and irrigation techniques for dry areas, as well as the introduction of high-quality varieties into production systems that will produce more cashews[7].

D. Problem Statement

Agriculture is not successfully cultivated using farmers' traditional methods. Not all the resources are used effectively. The inability of farmers to recognize due to ignorance and aging, crop diseases practices that frequently lead to soil nutrient deficiencies, degradation, and fatigue. Failure of the crop as a result occurs. In India, Cashew is grown in rainfed area having steep slopes or hilly areas, and in land that is not suitable for other crop cultivation. So called “Gold Mine of Waste land”. Though Cashew needs less manure and fertilizers for its productivity, in order to achieve a better yield, the soil must be maintained at an appropriate N:P:K ratio.

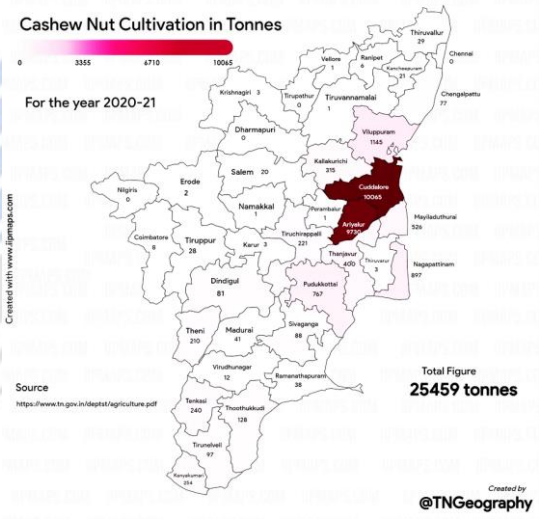

Figure 1. Cashew growing areas of TamilNadu

E. Soil Nutrients

To ensure sufficient organic matter in the soil, 10-15 kg of farmyard or compost manure should be applied per plant. Applying nutrients in an excessive or unbalanced manner damages soil and plant health as well as wastes resources and pollutes the environment. Just following the end of a big rainstorm is the perfect time to apply fertiliser. In a circular trench along the drip line, fertiliser should be applied. It is important to check that the soil has enough moisture before applying fertiliser. Pre-monsoon (May to June) and post-monsoon (September to October) seasons call for the fertilisers to be given in two separate doses. The post-monsoon season, when there is sufficient soil moisture, is the best time to apply a single dose, though. This is the time for Flushing and early flowering phase where roots activity is increased which will enhance the absorption of soil nutrients. This period is the best

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time for fertilizer application as the tree enters reproductive phase. A circular trench of 25 cm in width and 15 cm in depth should be dug at 1.5 metres from the tree trunk to apply fertiliser in sandy and laterite soils, soils of sloppy land and in areas with heavy rainfall that is West coast area. In Red loamy soils and in less rainfall area like East coast region, Fertilizers can be applied in a circular trench of

TABLE I. TAMIL NADU CASHEW VARIETIES

Cashew Variety	Cashew Nut yield (Kg/tree)	Cashew Nut wt (g)	Shelling (%)	Kernel wt (g)	Export Grade	Year	Germplasm Collected area in TamilNadu	Color of the Cashew Apple
VRI-1 (M10/4)	7.20	5.0	28.0	1.40	W320	1981	Vazhisothanaipalayam	Yellow
VRI-2 (M44/3)	7.40	5.10	28.3	1.45	W320	1985	Kattupalli	Pinkish Yellow
VRI-3 (M 26/2)	11.68	7.18	19.1	2.16	W210	1992	Edayanchavadi	Red
VRI-4 (M 26/2)	16.60	6.63	28.5	1.70	W240	2000	Vazhisothanaipalayam	Orange Red
VRI(CW) H1	16.50	7.2	30.5	2.2	W210	2009	Hybrid	Pinkish Red

TABLE II. MANURE AND FERTILIZER DOSE AS PLANT/YEAR

Plant Years	Organic Fertilizer	Inorganic Fertilizer (gm)		
	Farm Manure (kg)	N	P	K
I Year	10	70	40	60
II Year	20	140	80	120
III Year	20	210	120	180
IV Year	30	280	160	240
V onwards	50	500	200	300

about 50 cm at 0.5m distance from trunk for first year plant, 0.7m for second year plant, 1 m for third year and 1.5m for fourth year plant. There are a lot of different NPK ratios available, making it challenging to select the best one for our cashew trees. Choosing the one that will best suit our needs can be challenging.

II. LITERATURE REVIEW

Cashew is mostly grown in poorest regions of India on laterite, red, and coastal sands [5]. It is also grown in black soil of Tamil Nadu and some parts of Andhra Pradesh. Although it may be planted practically everywhere, it works best in well-drained, brown forest soils and red sandy soils. Coastal soil is loamy, light, and abundant in organic content. It may hold a lot of water. It is said that a significant fraction of soils used to grow cashews are acidic. Large and leathery leaves are observed and grows to the height of up to 60 feet. A pH ranges from moderately acidic to slightly alkaline (between 6 and 7) is needed for cashews growth in a well-drained soil. Also, it needs good sun shade for its growth. A few of the main obstacles to cashew development in acidic soils include: low soil pH, which is associated with issues like Al and Mn toxicity; low base saturation percentage; low accessible P and high P fixation capacity; low concentrations of exchangeable Ca, Mg, and K; reduced Zn, Mo, and P; and low concentrations of exchangeable Ca, Mg, and K.

A. Organic and Inorganic Fertilizers for Cashew

Biofertilizers can be applied to cashew seedlings to make the plant ability to absorb soil nitrogen and phosphorus. Cashew seedlings can be treated with Azospirillum for nitrogen absorption and Phospobacteria for Phosphorus uptake [15]. Adejumo [14] found that single and combined fertilizer application to cashew farm at Nigeria had better result on both cashew yield as well as disease index. For the first year [14] used the combination of urea at 120 kg/ha with MOP at 48 kg/ha and got good yield of 3.53 kg per tree and for the next year used 120 kg/ha, 144 kg/ha and 24 kg/ha of Urea, SSP and MOP respectively which was better than the first-year yield. According to research done at DCR Puttur, the application of 500 g N, 125 g P, and K, as well as 10 kg of poultry manure per tree per year under a normal density planting system (200 trees/ha) and 250 g N, 50 g P, and 10 kg of poultry manure per tree per year under a high-density planting system (625 trees/ha) both result in higher nut yields for rainfed cashew. For TamilNadu, the fertilizers' recommended dose for cashew is shown in the Table 2 [11]. Figure 2 shows cashew trees of different ages. In order to improve fruit set and nut yield in cashew, foliar sprays of nutrients (Urea 2 to 4%, DAP 1%, Orthophosphoric acid, ZnSO4 4%, and Cu 0.3 to 0.6%) are applied during the stages of flush, panicle initiation, and fruit set. In [8], Gavit et al treated Vengurla -4 of Kongan area with 13 fertilizer treatments and availability of soil nutrients along with application of 1.0:0.50:0.50 kg/tree of NPK and foliar

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application of boron and zinc through borax at 0.25 % and zinc sulphate at 0.5 %, and found beneficial in Konkan laterite soils. For the measurement of soil macronutrients (NPK), techniques like optical sensing, laboratory testing, ion-selective electrodes, chemical analysis, Inductively Coupled Plasma (ICP) spectroscopy, and fluorescence spectroscopy are used [12]. ELM method can be utilized for classification of soil nutrients [13]. Internet of Things is being used in various agriculture applications like Precision farming, soil moisture level identification, fertilizer recommendation with quantity, agricultural drones, climate conditions monitoring system, automated irrigation system, smart greenhouse, etc by using sensors of different types. When compared with conventional methods, Smart farming based on IoT is very efficient [4]. In Literature many machine learning and deep learning techniques are used decision making and for the recommendation of the fertilizer to be applied for various crop cultivation and fertilizer quantity recommendation. Various machine learning algorithms like Random Forest,

a.Cashew plant in 1 year

b. Cashew plant in 2 years

c.Cashew plant in 3 years

d.Cashew plant after 4 years

e.Cashew plant after 5 years

f.Cashew plant after 7 years

Figure 2. Cashew Plants with different ages

Linear Classifier, Linear Random classifier, Decision Tree Classifier, Fuzzy logic (JJI Haban et al 2020), SVM, KNN, Naïve Baye's, XG Boost, Voting Classifier are used for fertilizer recommendation of different crops. Deep learning seeks to accomplish this. The neural network grows in depth over time by adding layers, which improves performance. Deep learning algorithms like CNN, FCN-AlexNet and SegNet, DRQN (Lakshmi Devi et al 2022). [10] proposed Enhanced-IDCNN DLM based soil nutrient prediction and fertilizer recommendation with the accuracy of 99.7% for sustainable Groundnut cultivation.

III. METHODS

Exponential growth in Cashew production can be achieved by using Automation in Cultivation using recent technologies like AI (Machine Learning and Deep Learning Techniques), IOT etc. Adopting site-specific nutrient management based on soil and leaf analysis data is the best course of action for maximizing agricultural income and productivity. By creating suitable soil or foliar nutrient management regimens to boost the yield levels, Mangalassery et al. proposed leaf nutrient norms [2] that can be useful to correct the nutrient levels in cashew. Significantly in Cashew cultivation there were some differences between tree to tree in cashew orchards like tree age, tree growth, flowering, fruit maturity, tree yield, nut size etc. The proposed system provides solution for tree specific nutrient management of soil for cashew orchards. The framework of the proposed system is used to determine the rate of N, P, K availability of a specific cashew tree. As a result, the AI algorithms will identify the deficiency of the soil NPK values with the reference to the threshold values already known. Finally, the system will produce the recommendation of fertilizers which supplies significant amount of macronutrients (NPK) to the owner of the field.

A. System Architecture

We proposed a system model for nutrient management of cashew which includes both hardware and software setup using IOT and AI Technology. Figure 3 represents the hardware setup of the system includes major components like Arduino UNO, RS485 Module, NPK Sensor. We have chosen different trees for test samples in a particular orchard area for tree specific yield study. Around 500 sample trees were chosen which differs in yield like good yield tree, average yield and poor yield.

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B. Soil Sample Collection

Soil Samples were collected from various villages of Cuddalore district and from various farmlands of different farmers were collected. Soil sample collection was shown in the Figure 4. A total of 500 samples from Kumalankulam village, Nochikadu village and M.Puthur Village are studied for soil health. The Cover used for Sample Collection has an envelope with some details like Sample No., Tree Age, Diameter, Location. Kumalankulam and M.Puthur area soils are red loamy soil whereas flat land of Nochikadu village has large deposits of alluvial soil.

C. Determination of NPK using IOT

The proposed system for identifying NPK values of soil helps cashew farmers to get deficiency in soil heath of a particular tree for fertilizer application. The collected soil samples are analyzed using the proposed IOT system that will make use of NPK sensor. The NPK sensor calculate the ratio of N:P:K available in the soil samples. The NPK data provided by the sensors as shown in the figure 7 are then collected for creating data set which is then used by Machine learning algorithm. The soil fertility sampling by the sensor and NPK sensor used are given in the figure 5 and 6 respectively.

D. Fertilizer Recommendation using DL

In Cashew cultivation, farmers are advised to use direct fertilizers without using complex type of fertilizers. Market available complex fertilizers are not suitable for NPK recommended dose. The Proposed Fertilizer recommendation system uses AI technology to recommend required fertilizer ratio for farmers to apply in order to maximize the yield. In our proposed work, for training the model, data sets are created by using soil health cards from Indian Government,

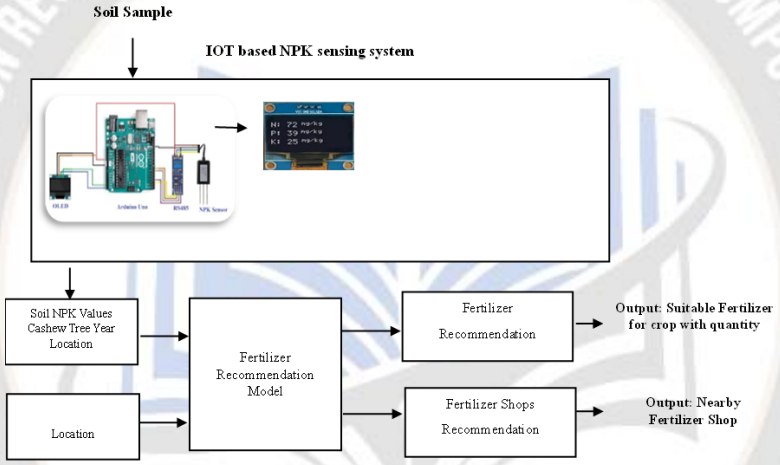

Figure 3. System Architecture of Proposed System

a. Red Loamy Soil Sample collection from Kumalankulam village, Cuddalore District

b. Sample sandy soil from Nochikadu Village, Cuddalore district

Figure 4. Soil Sample Collection in Cuddalore District

sensored data and fertilizer calculated reports from ICAR [6]. After creating dataset, the LSTM based RNN model with two layers of LSTM and one dense output layer. was trained with created dataset where input features are Nitrogen, Phosphorus, Potassium, Tree_Age, Soil_Type, PH and the output variables are Recommended_Fertilizer and Recommended_Fertilizer Quantity. The system uses AI trained model that will analyse the soil data provided by the IOT NPK sensor and recommend the tree specific needed fertilizer ratio. This tree specific recommendation will make the farmers to have knowledge on their land soil fertility level and know its deficiency before applying inorganic fertilizers. The system works on LSTM based RNN model to predict the fertilizer ratio based on the soil health data.

E. Intercropping

Plants that will host pests and diseases in cashew should be avoided for intercropping [9]. Based on soil quality and various

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climatic conditions and local situations, intercropping in cashew can be done using some annual crops like tapioca, pulses, turmeric, ginger, yam, maize, etc. Very suitable intercrops are leguminous crops like as groundnuts, horse gram, cowpea and beans. Based on experimental results, in cashew cultivation intercrop namely Groundnut provide better yield (Rs. 16,188/- per hectare) but Blackgram is considered as highest cost benefit intercrop for cashew. We can also cultivate some medicinal plants as intercrops. Best Profitable one is Aloe Vera.

IV. RESULTS

The proposed research work was done on cashew crop, where experimentation was carried out on various cashew trees with different ages, different productivity. As a result, different age of cashew trees with different NPK values based on tree location needs different dose of nutrient application with different quantity and also foliar application of major and minor nutrients at different period of crop growth namely fleshing, flowering and cashew nut developing.

Figure 5. Soil Testing Setup at Cashew Canopy

Figure 6. NPK Sensor Used

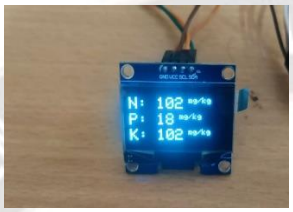

Figure 7. NPK values of Sample 1 from proposed IOT system

TABLE III. AVERAGE NPK AVAILABLE VALUES FROM THE MENTIONED AREAS MEASURED BY OUR PROPOSED IOT SYSTEM

Area	Soil Type	Values from NPK Sensor		
		Average N	Average P	Average K
Nochikadu	Sandy	196.3	19.45	189.1
M.Puthur	Red Loamy	143.6	21.1	177.7
Kumalankulam	Red Loamy	153.5	23	177.4
Average – Cuddalore Area		164.4667	21.18333	181.4

TABLE IV. SOIL NPK VALUE COMPARISON WITH SOIL LAB TESTING

Test Methods	NPK Sensor	Soil Lab Test
Testing Time	60 sec	10 days-20 days
Sample 1 – Kumalankulam	N-195 P-17 K-142	N-210 P-19 K-156
Sample 2 – M.Puthur	N-134 P-26 K-159	N-143 P-22 K-152
Sample 3 – Nochikadu	N-248 P-16 K-124	N-212 P-18 K-142

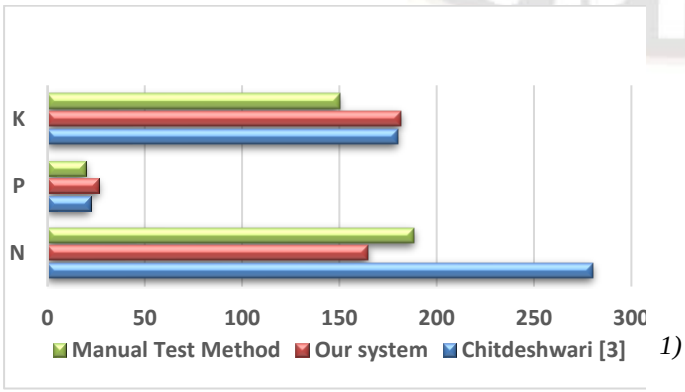

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Figure 7. Comparison of NPK values measured by our method with other methods available

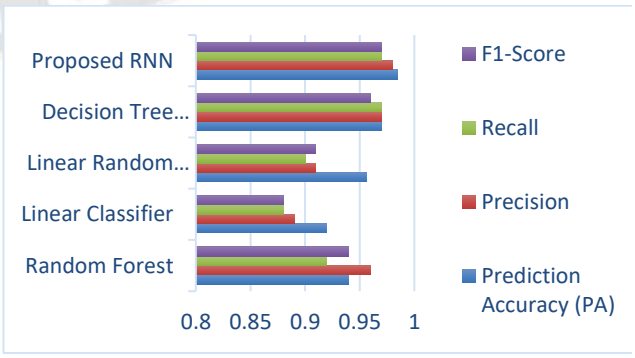

Figure 8. Comparison of performance metrics by various Models with proposed RNN

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Cashew tree growth and yield were recorded in different stages of cashew season time and analyzed for knowing the impact of applying suitable fertilizer with recommended dose in tree specific manner. In Table III the average NPK values of experimented areas which is measured by our IOT system is given. The result of NPK sensor was compared with the values of NPK values provided in Soil Health Card provided by Government of India, Ministry of Agriculture and Farmers Welfare, Department of Agriculture and Farmers Welfare for the particular land area and it is shown in Table IV. As in figure 7, The NPK values by the proposed system is analyzed for its accuracy by comparing the results with [3] and Soil lab test values. For this comparison, the soil fertility of the experimental area was determined by the proposed system and standard soil lab testing method to know the difference of three macro nutrients (NPK) of the soil.

The evaluation of the proposed work was done with the cashew nutrients dataset of Cuddalore district. Performance Metrics like Prediction Accuracy, Precision, Recall and F1-Score are calculated for LSTM -RNN for fertilizer recommendation with dosage level and compared with other baseline models and it is graphically represented in Figure8.

The overall error measures of the work are given below in Figure 9.

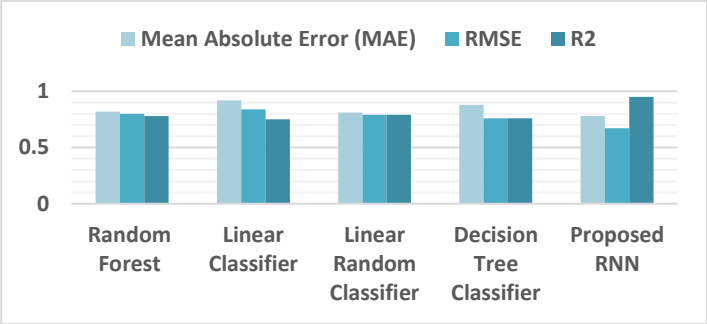
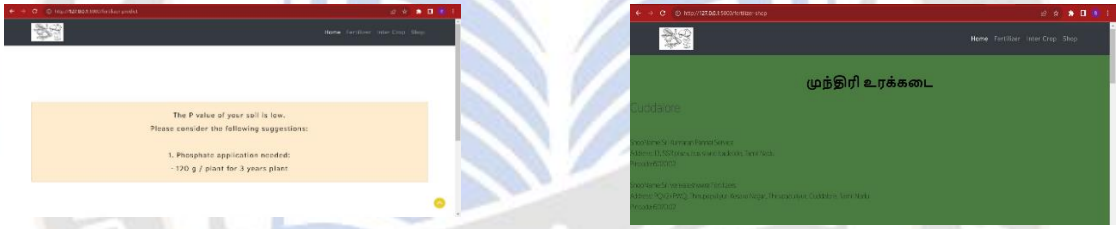


Figure 9. Error Metrics of various models with proposed RNN

Figure 10 a is the result produced the proposed fertilizer recommendation model using neural network for a given input features like N, P, K values from NPK sensor, Soil type, Tree age. The output of the cashew recommendation system



a.Result of the system and suggested dose for yield improvement b.Fertilizer shop recommendation based on the location of the farmer

Figure 10. Recommendations of the soil nutrient management and fertilizer recommendation system with fertilizer shop suggestions based on the location of the farmer

for fertilizer shop suggestion as per farmer's location is shown in Figure 10 b. The result of performance metrics and error measures reveal that the proposed RNN – LSTM model is better in terms of all metrics for fertilizer recommendation with proper dosage to enhance tree specific yield by suggesting deficiency-based quantity based on the cashew tree age factor.

V. DISCUSSION

From our proposed work, it was observed that in Cuddalore district, the overall available Nitrogen of the soil was low, Phosphorus was high and medium in available Potassium. Nitrogen level of overall Cuddalore District regions is below 164.46 kg ha^{-1}. The availability of Phosphorus in Cuddalore district was high and mostly above 22 kg ha^{-1} except some areas of Virudhachalam where the level of Phosphorus is about 11 to 22 kg ha^{-1}. Potassium in Cuddalore district is in the range between ranges from 110 to 350 kg ha^{-1} and average of 181.4 kg ha^{-1}. To match with crop needed NPK, Farmers should apply fertilizer rich in Nitrogen like Urea for younger plants especially as it needs more Nitrogen. Nitrogen fertilizer for older age trees can be minimized as it doesn't require much nitrogen. The phosphorus and Potassium level of the Cuddalore district is medium whereas cashew cultivation needs more P and K for better growth and yield than N. Farmers can go with fertilizer applications rich in P and K for cashew cultivation.

VI. CONCLUSION

Inorganic fertilizer application to the crop without proper knowledge of Soil Nutrient deficiency affects soil fertility in the future. Cashews are cultivated in various parts of Tamil Nadu, a state in India. Though it has more commercial value and rich nutritional benefits, Cashew seems to be a neglected orphan crop among farmers. As a result they are not ready to supply enough fertilizers to the cashew crop. It was proven that proper fertilization and irrigation double the yield and make the crop free from disease attack. All the cashew varieties give an average yield of 8 kg/tree. To get better productivity and more income, farmers need to adopt the strategy of site-specific and

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tree-specific soil nutrient management. Through this research work, tree specific nutrient management system was developed with the accuracy of 98.57 % using LSTM based RNN for fertilizer prediction based on input features and NPK sensor for testing soil NPK of a tree. The work result shows that in the Cuddalore district, India nitrogen level in the soil is very low. By the application of recommended dose predicted based on the tree specific NPK test values from NPK sensor, it was proved that farmers can harvest cashew about 50% increase in the yield. The tree specific application of treatment resulted with good profit gains when compared to uniform application. This work will highly contribute precision Agriculture and reduction on investment which will help us to involve optimize fertilizer doses by the cashew farmers of Tamil Nadu.

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