D-5586
[1-7]

A Lagrange Interpolation Application for Automating Fertilizer Distribution in Agriculture using Wireless Sensor Networks

Santosh Trimbak Warpe, Ravi Kumar Singh Pippal

10.18805/ag.D-5586

ABSTRACT

Background: Agriculture is the linchpin of the Indian economic system which extraordinarily dependent on soil, use of fertilizer and climate conditions. Soil fertility depletion is a reason for the problem of Indian agriculture. Not only the usage of plant vitamins per hectare is fairly low and imbalanced, but also the Indian farmers are still using the traditional method to spread the fertilizer in the field which is the predominant reason for low crop yields. It also influences people via consumption. So, there should be a precision and constancy tracking mechanism in agricultural merchandise and use of fertilizers inside the farm. In this paper, the implemented system presents a method for the distribution of required fertilizer for crop acreage. To optimize this, the wireless sensor gives a systematic answer for fertilizer distribution using Lagrange's Interpolation (LI).

Methods: The experiment was carried out in the MIT Academy of Engineering's Agrotech Farm in Pune over the last one year (2019-2020). The readings were taken from the tomato crop. We used the LI to evaluate the values between Standard, Conventional and Actual, which delivers the optimal value and reduces fertilizer waste and farmers' financial burden. These LI may result in a decrease in the number of sensor nodes in the agricultural field. The decrease in sensor nodes lowers total operating costs.

Result: With an equally and unequally spaced approach, in comparison to a conventional strategy the implemented system saves nitrogen (N), phosphorus (P) and potassium (K) by just giving the crop with the required amount of fertilizer.

Key words: Fertilizer, Nitrogen, Phosphorus, Potassium, Wireless sensor networks.

INTRODUCTION

India has a population of around 1000 million people. It's far the seventh biggest state within the international with a geographical vicinity of 328.7 million/ha. Agriculture is the backbone of the Indian economy, contributing about 22 percent of Gross Domestic Product (GDP) and supplying a livelihood to two-thirds of the population [16]. In order to ensure the well-being of India's expanding population, it is necessary to do a comprehensive analysis of India's climate, soil and fertiliser consumption before developing effective land-use policies. Balanced and adequate fertilization is critical for increasing crop yields and ensuring sustainable agriculture. No developed or developing country has been able to grow agricultural production without increasing the usage of balanced fertilization. In reality, nations in which consumption of plant nutrients is low and imbalanced, agricultural manufacturing is also low and yields are stagnant or declining. So, to overcome this problem in this paper authors have used the approach LI which offers accurate fertilizer distribution concerning each crop. The carried-out machine will take the values from the sensor that are to be had inside the field. Those values are then in comparison with trendy values. If the value is less than the applied device will take a selection for the delivery of a required quantity of N/P/K values.

We can optimize the use of fertilizer in the farm using the Newton Backward Difference (NBD) which reduced working cost and economic burden on the farmers (Warpe *et al*. 2022). The implemented system demonstrates that how Newton Forward Difference (NFD) approach saves the quantity of N/P/K with the aid of imparting required value to the crop in assessment with the traditional method (Warpe *et al*. 2020). We can increase the yield of garlic inside the Bangladesh to satisfy the call for of the humans in spite of the dearth of the land. The experiment named as "Pot" accomplished in the internet located in the Agriculture University, Bangladesh. Six ranges of values for potassium (K) used. Growth inside the garlic yield with the growing cost of k wherein K=2 hundred kg ha^{-1} is appropriate for purchasing maximal yield (Jiku *et al*. 2020). They developed the precision law version of Water and Fertilizer for Alfalfa in agriculture based totally on cyber physical gadget. This model has biophysical submodel, the computation submodel of water and fertilizer regulation and the interplay of the sub models for each. It interacts with the alfalfa boom and precision regulation of water in area (Liu *et al*. 2020). It had

Vedica Institute of Technology, Ram Krishna Dharmarth Foundation University, Bhopal-462 033, Madhya Pradesh, India.

Corresponding Author: Santosh Trimbak Warpe, MIT Academy of Engineering, School of Computer Engineering and Technology, Alandi (D.), Pune-412 105, Maharashtra, India.
Email: stwarpe@mitaoe.ac.in

How to cite this article: Warpe, S.T. and Pippal, R.K.S. (2022). A Lagrange Interpolation Application for Automating Fertilizer Distribution in Agriculture using Wireless Sensor Networ Agricultural Science Digest. DOI: 10.18805/ag.D-5586.

Submitted: 21-03-2022 **Accepted:** 25-06-2022 **Online:** 23-07-2022

studied and decided the specified amount of starter N application which could inflate N2 fixation and soybean seed yield the use of Rhizobial Immunization and exclusive nitrogen doses (Getachew *et al*.2020).

The Setinel-2 satellite records used for the mapping of Nitrogen uptake for plant life indices in three one of a kind environmental condition. The simple ratio crimson part had the highest overall performance amongst all of the methods. The simple ratio red edge had the highest performance among all the methods (Sharifi *et al*.2020). It has been proved that the leaf N content material of strawberry is profoundly affected with the aid of cultivar variation and organizing a multi-cultivar version is beneficial in tracking the nitrogen fame and guiding N fertilization pointers for extraordinary strawberry cultivars (Wu *et al*. 2020).

We had demonstrated a novel approach for coupling DayCent, a single species model to APSIM, a multi-species version, to boom the capability of DayCent when representing a number of grass-legume fractions. While depending on precise assumptions, each can capture the key elements of the grass-legume growth, including biomass manufacturing and BNF and to correctly simulate the interactions among converting legume and grass fractions, especially mixtures with a high clover fraction (Nuala *et al*. 2019). The need to refill K nutrient shares in western Kenya, specifically in fields beneath non-stop cultivation which have not acquired K fertilizer or livestock manure. Fertilizing with NPK supplied consistently accurate yields throughout all fields. An evaluation of animal manure within the past as a primary step within the direction of progressed fertilizer use pointers for small-holder farmers (Njoroge *et al*. 2019). After analyzing the FH, received from microbial processing of abundant and less expensive feathers, will be a candidate N-wealthy fertilizer for lettuce cultivation (Lisiane *et al*. 2019). Amending soils under upland rice cropping machine with rice husk biochar will lessen N fertilization requirement, at the same time as sustainably realizing the yield capability of upland rice (Segun *et al*. 2019).

The purpose of the experiment was to determine that N stress takes place and intensifies earlier than the corn tasseling degree at experimental site, which permits sufficient time window to come across the stress and take treatment operations (*i.e.,* side dressing). The early N stress may be alleviated or even disappear later on with the facet dressing. The UAV- and CubeSat-based totally multispectral sensing have the promising capability to screen N pressure of corn for the duration of the developing season (Yaping *et al*. 2019). The linear interpolation to wish a foothold the water distribution supported the crop requirements (Giri and Pippal 2017). The method determined the mixture of inorganic (NP) fertilizer and excreta-primarily based vermicompost for great financial yield and tomato (Tesfu *et al*. 2017). Our findings highlight that N fertilizer with the addition of biochar drastically stimulated soil nitrification and shifted the AOB abundance and network (Bi *et al*.2017). WSN can also be used to distribute the fertilizer effectively (Warpe and Pippal 2016).

Wireless sensor networks

Wireless Sensor Networking is a rising era that promises a huge range of capability programs in both civilian and army areas. A wireless sensor network (WSN) commonly consists of a massive range of low price, low power and multifunctional sensor nodes that are deployed in a region of interest. Those sensor nodes are small in length however are equipped with sensors, embedded microprocessors and radio transceivers. Consequently, they have not only sensed but additionally data processing and speaking skills. They speak over short distances via a wireless medium and collaborate to accomplish a commonplace mission, for example, surroundings tracking military surveillance and business process management. In many WSN packages, the deployment of sensor nodes is executed in an advert hoc fashion without cautious preplanning and engineering. Once deployed, the sensor nodes need to be able to autonomously arrange themselves right into a twine-less communication community.

It is typical for sensor nodes in unique to be powered by batteries and they must function without human intervention for an extremely extended period of time. In maximum cases, it's far very difficult and even not possible to trade or recharge batteries for the sensor nodes. Outstanding from traditional wireless networks, WSNs are characterized by denser degrees of node deployment, better reliability of sensor nodes and extreme electricity, computation and memory constraints. The topology of the WSNs will vary from a simple star community to an advanced multi-hop wireless mesh network.

MATERIALS AND METHODS

The balanced application of fertilizer has no negative impact on profit or output. An unbalanced application of fertilizer's value results in a lack in the nutrients that are necessary for accelerating the growth of the soil. We employed the LI approach to make the best use of the fertilizer.

Lagrange's interpolation

Before planting any crop, spacing is undoubtedly a crucial consideration. The spacing of your plants has a big influence on your total growth per acre. If you pick the appropriate spacing for your area, you will achieve the greatest results in terms of productivity. We know that crop growth solely depends on the use of fertilizer, especially macronutrients *i.e.* Nitrogen (N), Phosphorus (P) and Potassium (K). If we are giving more fertilizer then healthy growth and yield never be possible which also leads to a reduction in soil fertility. If we are giving less fertilizer then it leads to a deficiency.

The deployment of WSN nodes to get the mean values of environment parameter values which plays very important role. Whenever the field area is even /planer, the mean value results are better with equidistant placements of nodes. But, it doesn't work more efficiently if the field is uneven / nonplanar. To achieve the required mean values, nodes can be deployed in non-equidistant manner. This type of deployment gives parameter mean values close to at actual. The mean value difference with actual values will be greatly reduced.so, the efficiency will increase and NPK distribution would be close to as per required values.

Using LI, our automated system takes care of all the problems by giving the necessary fertilizer based on the crop type. It compares threshold values to turn the valve ON/OFF. As a result, available fertilizer can be used efficiently and optimally to reduce farmer losses, resulting in higher yield.

The task is to find the value of the unknown function y at a given point x. The LI method finds the approximate value of y at a given value of x.

If x_o, x_1, x_2...... xn are given set of observations (Nodes) which are need not be equally spaced and let y_o, y_1, y_2..... yn (N/P/K values) are their corresponding values, where y= f (x) be the given function

$$\text{Then } f(x) = \frac{(x-x_1)\ (x-x_2)\ldots(x-x_n)}{(x_0-x_1)\ (x_1-x_2)\ldots(x_0-x_n)}\, y_0 +$$

$$\frac{(x-x_0)\ (x-x_2)\ldots(x-x_n)}{(x_1-x_0)\ (x_1-x_2)\ldots(x_1-x_n)}\, y_1 + \ldots + \frac{(x-x_0)\ (x-x_1)\ldots(x-x_{n-1})}{(x_n-x_0)\ (x_n-x_1)\ldots(x_1-x_{n-1})}\, y_n$$

This is known as the Lagrange's formula which is used for both equally and unequally spaced arguments.

Procedural steps

1. Start.
2. Slave node reads NPK values from Rapitest 1818 Mini 4 in 1 Soil Tester.
3. Send values to signal conditioner for noise reduction then ADC conversion.
4. Setting Threshold values.
   i. Manual threshold setting.
   ii. Automatic threshold setting using interpolation.
5. Apply LI to calculate the average.
6. Display values on device and store in database.
7. Retrieve that data through database.
8. Stop.

Experiment setup

The authors' primary goal is to create an automated fertilizer delivery system that delivers additional features while decreasing farmer interaction. Based on the brink value, the system is capable of dispensing the required N/P/K value. The

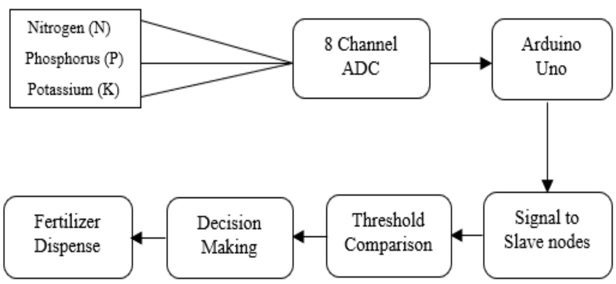


Fig 1: Block diagram.

Fig 1 shows the block diagram consist of the following compononts.

Fertilizer

Fertilizers can be divided into macronutrients and micronutrients. There are 9 types of essential macronutrients among which NPK stands on top. NPK sensor gives the available values readings in that field. Based on that we can decide which crop yield should be taken.

Sensor array

For calculating f(x), it will take two inputs

1. From different sensors *i.e.* Nitrogen (N), Phosphorus (P) and Potassium (K).
2. No. of day's (y).

8Channel analog to digital converter (ADC)

Used to convert the analog signal generated to the digital data. It uses signal conditioning to remove noise level received in raw form.

Arduino Uno R3

PU, RAM and ROM are the components of microcontrollers. Because the microcontroller uses TTL protocol and our base-station unit uses binary values, we utilize an Arduino Uno R3 for communication between the microcontroller and the base-station. It operates on the basis of serial communication.

ThingSpeak

To store, process and analyze data, we're using an open source IoT platform. The Rapitest meter gathers available soil values and combines them for N, P and K fertilizer. Readings were conducted every 8 days to get the average value. These values must be saved on a platform that is available 24 hours a day, seven days a week.

Darlington drivers

Darlington drivers play an important part in supplying the needed value for device on/off. The suggested system would make a choice for the delivery of a needed amount of N/P/K values based on the comparison of sensor data with standard values.

Feedback circuitry

Used to take feedback using ATmega32. It also used to store generated data from ADC to Log.

RESULTS AND DISCUSSION

The combined values available from the Master and Slave nodes are shown in Fig 2. Fig 3 depicts all of the sensor's readings during the course of the period. All of the readings were saved in the private channel on ThingSpeak for analysis.

The weekly NPK usage for the tomato crop is shown in Table 2. It focuses primarily on three key parameters: standard, conventional and actual values.

· Standard: Denotes the amount of fertilizer required for proper tomato crop development and maximum capitulation.

· Conventional: Denotes the farmers' distribution of fertilizer during the growing of the tomato crop, excluding any atomization.

· Actual: Denotes the amount of required fertilizer applied to the tomato crop during LI cultivation.

Comparative graphs

Fig 4, 5 and 6 shows the comparative graph analysis of the nitrogen, phosphorus and potassium use with respective to Standard, Conventional and Actual values for the said crop. To represent the graphs on the x axis Weeks and y-axis values are used.

Discussion

Table 1 represents the standard NPK values for tomato crop which are used to compare with at actual values. Table 3. shows the efficiency of NPK for LI. For calculation, we have used Standard, Conventional and Actual values for the

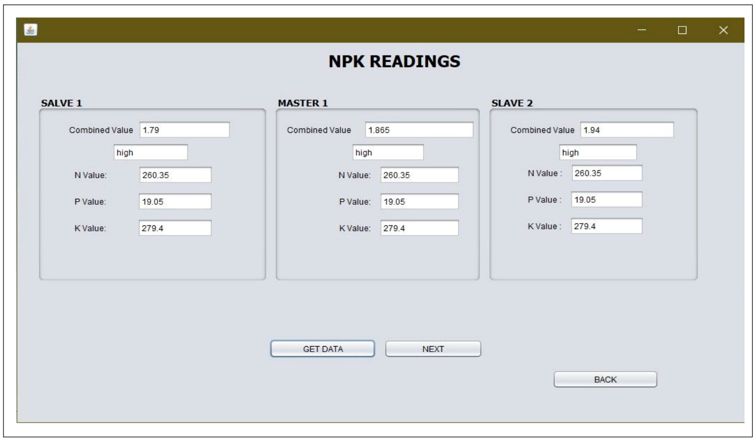
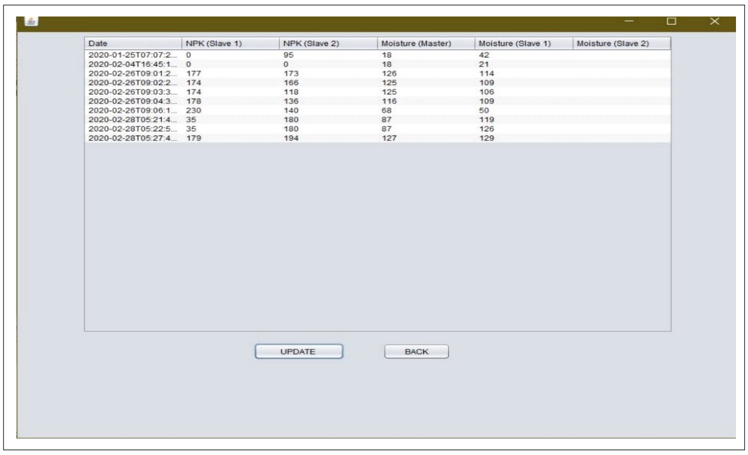


Fig 2: NPK readings for Master and Slave.



Date	NPK (Slave 1)	NPK (Slave 2)	Moisture (Master)	Moisture (Slave 1)	Moisture (Slave 2)
2020-01-25T07:07:2...	0	95	18	42	
2020-02-04T16:45:1...	0	0	18	21	
2020-02-26T09:01:2...	177	173	126	114	
2020-02-26T09:02:2...	174	166	125	109	
2020-02-26T09:03:3...	174	118	125	106	
2020-02-26T09:04:3...	178	136	116	109	
2020-02-26T09:06:1...	230	140	68	50	
2020-02-28T05:21:4...	35	180	87	119	
2020-02-28T05:22:5...	35	180	87	126	
2020-02-28T05:27:4...	179	194	127	129	

Fig 3: NPK readings stored on ThingSpeak.

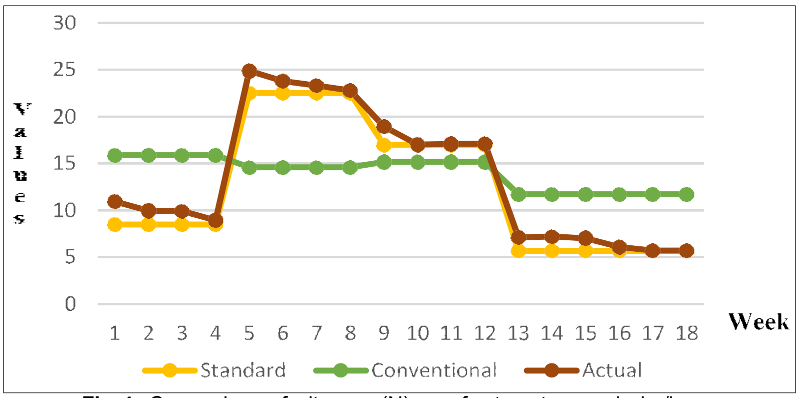


Fig 4: Comparison of nitrogen (N) use for tomato crop in kg/ha.

Table 1: NPK fertilizer distribution table for tomato as follows.

Cultivation period (In weeks)	→	1 to 28 (4 Weeks)	29-56 (4 Weeks)	57 -84 (4 Weeks)	85-126 (4 Weeks)	Total
Nitrogen (N)	%	15	40	30	15	100
	Kg/ha	34	90	68	34	225
Phosphorus (P)	%	20	35	35	10	100
	Kg/ha	23	39	39	11	113
Potassium (K)	%	15	30	35	20	100
	Kg/ha	17	34	39	23	113

Table 2: Utilization of NPK (weekly).

	N			P			K		
Week	Kg/ha			Kg/ha			Kg/ha		
	Standard	Conventional	Actual	Standard	Conventional	Actual	Standard	Conventional	Actual
1	8.5	15.59	10.16	5.75	7.75	6.54	4.25	8	4.95
2	8.5	15.59	9.17	5.75	7.75	6.1	4.25	8	4.56
3	8.5	15.59	9.11	5.75	7.75	6.09	4.25	8	4.4
4	8.5	15.59	8.8	5.75	7.75	5.77	4.25	8	4.29
Total	34	62.36	37.24	23	31	24.5	17	32	18.2
5	22.5	14.58	24.23	9.75	7.5	10.89	8.5	7.75	8.77
6	22.5	14.58	23.75	9.75	7.5	10.31	8.5	7.75	8.7
7	22.5	14.58	23.1	9.75	7.5	10.03	8.5	7.75	8.63
8	22.5	14.58	22.6	9.75	7.5	9.13	8.5	7.75	8.51
Total	90	58.32	93.68	39	30	40.36	34	31	34.61
9	17	15.16	18.93	9.75	8	10.5	9.75	7.5	10.45
10	17	15.16	17.01	9.75	8	9.9	9.75	7.5	10.27
11	17	15.16	17.13	9.75	8	9.6	9.75	7.5	9.99
12	17	15.16	17.21	9.75	8	9.5	9.75	7.5	9.8
Total	68	60.67	70.28	39	32	39.5	39	30	40.51
13	5.66	11.71	8.41	2	5.16	3.03	3.83	5.16	4.67
14	5.66	11.71	7.3	2	5.16	2.28	3.83	5.16	4
15	5.66	11.71	7.16	2	5.16	2.15	3.83	5.16	3.94
16	5.66	11.71	6.66	2	5.16	2.1	3.83	5.16	3.9
17	5.66	11.71	5.95	2	5.16	2.03	3.83	5.16	3.79
18	5.66	11.71	6.1	2	5.16	2	3.83	5.16	3.8
Total	34	70.3	41.58	12	31	13.59	23	31	24.1

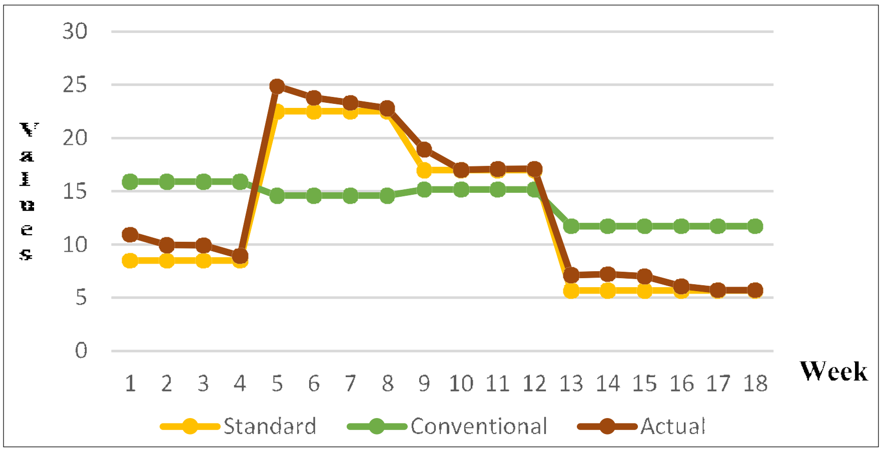


Fig 5: Comparison of phosphorus (P) use for tomato crop in kg/ha.

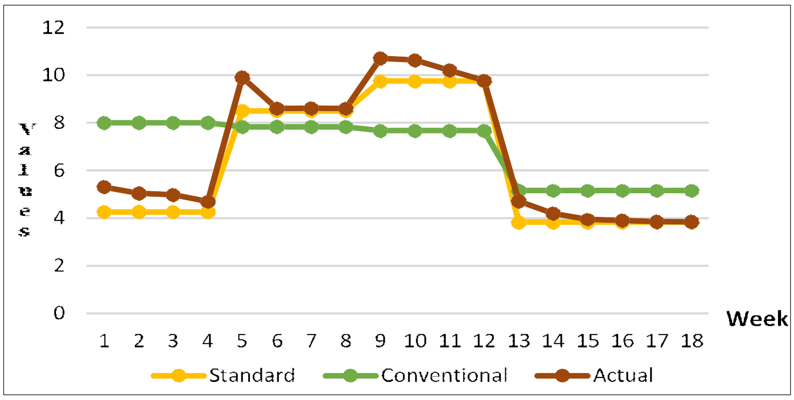


Fig 6: Comparison of potassium (K) use for tomato crop in kg/ha.

Table 3: The efficiency of NPK.

Fertilizer ↓	Efficiency (%) LI
N	96.48
P	95.12
K	94.69

tomato crop. For N, the standard value is 226, Conventional is 251.65 and the final value through LI is 242.8. For P, the standard value is 113, Conventional is 124 and the final value through LI is 118. For K, standard value for the said crop is 113, Conventional is 124 and the final value through LI is 117.4. LI is more efficient as we are using unequally spaced approach.

In general, it has been noted in prior work that a sensor node functions for a certain geographical region of 5 Sqr^m. So, if we take a land area of one acre, we will need to install 799 sensor nodes with a capacity of five Sqr^m, since one acre of land spans 3999 Sqr^m. However, in implemented method, fewer nodes are used with the same area coverage (200 nodes per acre) and intermediate values are derived using Linear Interpolation.so, the number of sensor nodes drastically gets reduced and hence it leads to reduction in system deployment cost. With the reduced cost and no. of sensor nodes so many farmers can make use of the system.

CONCLUSION

The results demonstrate the distinction in usage between conventional and actual methods. In comparison to the conventional approach, LI saved 3.51% of nitrogen, 6.94% of phosphorus and 7.65% of potassium. It lowers farm costs, manpower requirements and farmer burden.

ACKNOWLEDGEMENT

The authors would like to thank all the authorities of RKDF University, Bhopal and MIT Academy of Engineering, Alandi (D), Pune, India for providing their academic support.

Conflict of interest: None.

REFERENCES

Bi, Q.F., Chen, Q.H., Yang, X.R., Li, H., Zheng, B.X., Zhou, W.W., Liu, X.X., Dai, P.B., Li, K.J., and Lin, X. Y. (2017). Effects of combined application of nitrogen fertilizer and biochar on the nitrification and ammonia oxidizers in an intensive vegetable soil. AMB Express. Volume 7(1).

Getachew, Z., Gebrehana and Abeble, L. (2020). Response of soybean to rhizobial inoculation and starter N fertilizer on nitisols of Assosa and Begi Areas, Western Ethiopia. Springer Open, Environmental Systems Research. 9(14).

Lisiane, S., Rodrigo, R., Elci, G., Gustavo, B., Douglas, K., Daniel, D. (2019). Feather hydrolysate as a promising nitrogen- rich fertilizer for greenhouse lettuce cultivation. International Journal of Recycling of Organic Waste in Agriculture. (Suppl 1). 8: S493-S499.

Liu, R., Zhang, Y., Ge, Y., Wei, H. and Baiping, S. (2020). Precision regulation model of water and fertilizer for alfalfa based on agriculture cyber-physical system. IEEE Access. 8: 38501-38516.

Giri, M.B. and Pippal, R.S. (2017). Use of Linear Interpolation for Automated Drip Irrigation System in Agriculture using Wireless Sensor Network, International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS), Chennai. pp. 1599-1603. 2017.

Jiku, M.A.S., Alimuzzaman, M., Singha, A., Rahaman, M.A., Ganapati, R.K., Alam, M.A. and Sinha, S.R. (2020). Response and productivity of garlic [*Allium sativum* (L.)] by different levels of potassium fertilizer in farm soils. Springer Open Bulletin of the National Research Centre. 44(9).

Njoroge, S., Antonius, G.T., Schut, Ken, E., Giller, Zingore, S. (2019). Learning from the soil's memory: Tailoring of fertilizer application based on past manure applications increases fertilizer use efficiency and crop productivity on Kenyan smallholder farms. European Journal of Agronomy. 105: 52-61.

Nuala, F., Bindib, M., Brillib, C.L., Cichotad, R., Dibarib, C., Fuchse, K., Huguenin-Elief, O., *et al.* (2019). Modelling biological N fixation and grass-legume dynamics with process based biogeochemical models of varying complexity. European Journal of Agronomy. 106: 58-66.

Santosh, T.W., Pippal, R.S. (2016). A Study of fertilizer distribution system for agriculture using wireless sensor networ, International Journal of Computer Applications. vol. 147(2). pp.43-46, http://www.fao.org/3/a0257e/A0257E02.htm,DOA:10/02/2022.

Segun, O., Adeyemo, A., Awodun, M., Ajayi, A., Fasina, A. (2019). Effects of biochar and nitrogen fertilizer on soil physicochemical properties, nitrogen use efficiency and upland rice (*Oryza sativa*) yield, International Journal of Recycling of Organic Waste in Agriculture grown on an Alfisol in Southwestern Nigeria. 8: 295-308.

Tesfu, M., Gebrekidan, H., Kibret, K., Woldetsadik, K., Shimelis, B., Yadav, H. (2017). The integrated use of excreta-based vermicompost and inorganic NP fertilizer on tomato [*Solanum lycopersicum* (L.)] fruit yield, quality and soil fertility, International Journal of Recycling of Organic Waste in Agriculture. 6: 63-77.

Warpe, S.T., Pippal, R.S. (2020). Automated intensification of fertilizer distribution in agriculture using wireless sensor network. International Conference on Innovative Trends and Advances in Engineering and Technology (ICITAET). SHEGAON. pp 10-14.

Warpe, S.T. and Pippal, R.K.S. (2022). Newton backward difference application for automating fertilizer distribution in agriculture using wireless sensor networks. Agricultural Science Digest. DOI: 10.18805/ag. D-5455.

Wu, G., Jiang, Q., Bai, Y., Tian, C., Pan, W., Jin, X. and Zhang, B. (2020). Nitrogen status assessment for multiple cultivars of strawberries using portable NIR spectrometers combined with cultivar recognition and multivariate analysis. IEEE Access. 8: 126039-126050.

Yaping, C., Guan, K., Nafziger, E., Chowdhary, G., Peng, B., Jin, Z., Wang, S. and Wang, S. (2019). Detecting in-season crop nitrogen stress of corn for field trials using UAV- and cubesat-based multispectral sensing. IEEE Journal of selected topics in applied earth observations and remote sensing. 12: 12.