Analysis of Soil Nitrogen (N), Phosphorus (P) and Potassium (K) Estimation Methods: A Literature Review

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Abstract **- Soil information approach is associated with the integrated agricultural rendering practice. Nitrogen (N), Phosphorus (P), and Potassium (K) are the imperative supplement plants demands in the bulkiest extent. The stereotyped technique (Physicochemical investigation) used for disclosure of nitrogen in soil is compound and stagnant. Ample variety of N, P, K nutriments in the soil assures excellent plant growth which results in high quality produce with enhanced annual production yields. Farm supervisors also have a condemning liability of estimating the NPK levels in soil. This paper addresses the review of the methods that has been used for determining the soil N, P, K contents from the soil as over-fertilization results in groundwater pollution or toxic aggregation of enzymatics in the soil.**

Index Terms **- Nitrogen (N), Phosphorus (P), Potassium (K), Spectroscopy, DNN, CNN, RNN.**

I.INTRODUCTION

Soil organic matter (SOM) content, a crucial indicator of soil fertility, substantially impacts the physicochemical properties as well as soil attributes; hence for scientific fertilization, SOM contents should be analyzed. The fundamental soil organic constituent contempt is nitrogen (N), phosphorus (P) and potassium (K). Visible (VIS, 400-780 nm) and near-infrared (NIR, 780–2526 nm) spectroscopy is a favorable and competent technique for instantly and inexpensively monitoring SOM [1], since spectral reflectance of soil is negatively correlated with the SOM content and the SOM content could be obtained from measured soil reflectance spectrum [2, 3]. Many studies have recommended and tested discrete spectral data modeling techniques, along with linear regression (LR), partial least squares regression (PLSR), back-propagation (BP) neural network (BPN), and support vector machine (SVM).

Organic matter and consequentially soil organic material are vital constituent of soil that affect its physicochemical properties such as soil structure, water holding capacity, and Cation Exchange Capacity (CEC), in addition to its direct influence on soil resistance to erosion. Therefore, the spatial measurement of SOM content is essence for a vast range of environmental and agricultural practice. Traditional laboratory strategy for determining SOC is expensive, catastrophic, and gradual. Therefore, there is an increasing obligation for rapid, cost-effective, nondestructive, and sufficiently accurate approaches for predicting SOC under field conditions using either portable or on-line sensing infrastructure. Visible and near infrared reflectance spectroscopy (VNIRS) is reported to be a promising technology for soil analysis [4, 6]. Due to the availability of robust and portable detectors, VNIRS has been widely used for the in situ o-line and on-line predictions of various soil properties including SOM. SOM is indeed a key parameter widely used for soil quality assessment and is considered as one of the most commonly and successfully predicted parameters using VNIRS due not only to the direct spectral response SOC has in the NIR spectral range, but changes in the soil color that are associated with changes in the soil organic matter content detectable in the visible (VIS) range [4, 12, 13]. Once the spectral features have been calibrated for SOC prediction using chemo metrics or machine learning techniques, VNIRS can provide a rapid and cost-effective estimation of SOC in field conditions.

This research focuses on infrared imaging-based soil NPK levels analysis and prediction using neural network platforms. The neural network platforms may constitute models based on deep neural networks (DNN) such as convolutional networks (CNN) or recurrent neural networks (RNN).

II. LITERATURE SURVEY

In [1], Soil, being the medium for plant growth serves as the primary nutrient source. Nitrogen (N), Phosphorus (P), and Potassium (K) are the vital nutrients plants need in the largest amounts. There should be sufficient quantities of these nutrients in the soil to ensure optimum plant growth resulting in high quality crops and improved crop yields. Farm managers then have a critical responsibility of assessing the NPK levels in soil. Soil chemical analysis was the reference method used to define soil NPK levels. Near Infrared (NIR) Spectroscopy was adopted as a non-destructive, fast, and environmentally friendly method for determining characteristic absorbance spectra of soil. The resulting variations in the measured NIR absorbance wavelengths ranging from 1240 nm to 1480 nm were evaluated and used to characterize the NPK nutrient levels of the various soil samples. Furthermore, the dataset was modelled and analyzed using Artificial Neural Network (ANN) to determine the relationship of the NIR absorbance data to the soil NPK nutrient levels. Based on the regression analysis, the model's training R is 0.998, the testing R is 0.996, the test R is 0.996 and the overall R is 0.998. This study proves that NPK soil nutrient levels can be characterized in terms of NIR absorbance spectra.

In [2], authors present a portable soil nitrogen detector by using a chip-scale Fourier transform infrared spectroscopy sensor to enable rapid detection of soil nitrogen, and a supporting software with functions such as spectral acquisition, background subtraction, and data storage was also program. The detector was used to detect the spectral data in the actual farmland environment. 120 randomly selected soil samples were used to calibrate soil nitrogen to soil reflectance using partial least squares. 76 randomly selected samples were withheld for validation. Results of the experiments indicated values for the coefficient of determination as high as 0.934, and root mean square error was 1.923. After the model was embedded in detector, 10 soil samples were tested for verification. The relative error between the predicted value and the real value was less than 13%, and the minimum relative error was 5.56%. The results verified that detector can initially realize the rapid prediction of soil nitrogen and provide a certain technical reference for miniaturization of portable detecting instruments.

In [3], authors have given a broadband photo acoustic spectrometric (PAS) system was established for the detection of heavy metal contaminants in soil. The heavy metal element lead (Pb) was selected as a preferred detection target. The near infrared photo acoustic spectra of contaminated soil samples with various concentrations of Pb were collected and the spectroscopic relationship between the soil absorption peaks and Pb concentrations was analyzed. Four advanced spectral preprocessing methods were explored to improve the robustness of the prediction model. Based on the maximal correlation coefficient and minimal root mean square error criteria of prediction, a two-layer feed-forward network with a continuum removing preprocessing method with a correlation coefficient as 0.96 was tested as the most appropriate method for Pb concentration prediction. This fact verifies that the broadband PAS evaluation methodology, as a nondestructive testing method, can be potentially used as an alternative quantification detection method of heavy metal contaminants in soil without the involvement of complicated sample pretreatment.

In [4], have given an experiment is to adjust fertilization based on crop needs and soil properties and to reduce the amount of fertilizer in soil without diminishing yield. The soil analysis technique focus on photon absorption characteristics of the major soil nutrients (nitrogen, phosphorus and potassium). The soil samples under test were first oven dried and then mixed with four types of fertilizer [KNO3, TSP, and NPK] in the concentration range of 0.02-10%. Near IR laser beam pass through the closed loop Mach- Zander Interferometer to reduce fluctuations related to beam path and interacts with soil sample. When IR radiations are focused onto a sample, the molecules in the sample will increase their vibration energy by absorbing energy at specific frequencies depending on the molecular geometry, bond strengths and atomic masses. The scattered beam is thus modified, creating a signature of the targeted object with peaks at the absorbing frequencies. This technique provided rapid, non-destructive and simultaneous determination of nitrogen, phosphorus and potassium concentrations in soil fertilizer mixtures.

In [5], an optical transducer is developed to measure and to detect the presence of Nitrogen (N), Phosphorus (P) and Potassium (K) of soil. Such transducer is needed to decide how much extra contents of these nutrients are to be added to the soil to increase soil fertility. This can improve the quality of soil and reduces the undesired use of fertilizers to be added to the soil. The N, P, and K value of the sample are determined by absorption light of each nutrient. The optical transducer is implemented as a detection sensor which consists of three LEDs as light source and a photodiode as a light detector. The wavelength of LEDs is chosen to fit the absorption band of each nutrient. The nutrient absorbs the light from LED and the photodiode convert the remaining light that is reflected by reflector to current. The system utilizes an Arduino microcontroller for data acquisition therefore the output from the transducer is converted into a digital display reading. Testing on various samples of soils, showed that the optical transducer can evaluate the amounts of NPK soil content as High, Medium and Low.

In [6] image processing and artificial neural network was used to efficiently identify the nutrients and pH level of soil with the use of Soil Test Kit (STK) and Rapid Soil Testing (RST) of the Bureau of Soils and Water Management: (1) pH, (2) Nitrogen, (3) Phosphorus, (4) Potassium, (5) Zinc, (6) Calcium, and (7) Magnesium. The composition of the system is made of five sections namely soil testing, image capturing, image processing, training system for neural network, and result.

In [7], the total nitrogen (TN) content in soil samples was detected in the spectral range of 900–1700 nm using a hyper spectral imaging (HSI) system. Characteristic wavelengths were extracted using uninformative variable elimination (UVE) and the successive projections algorithm (SPA), separately. Partial least squares (PLS) and extreme learning machine (ELM) were used to establish the calibration models with full spectra and characteristic wavelengths, respectively. The results indicated that the prediction effect of the nonlinear ELM model was superior to the linear PLS model. In addition, the models using the characteristic wavelengths could also achieve good results, and the UVE–ELM model performed better, having a correlation coefficient of prediction (rp), root-mean-square error of prediction (RMSEP), and residual prediction deviation (RPD) of 0.9408, 0.0075, and 2.97, respectively. The UVE–ELM model was then used to estimate the TN content in the soil sample and obtain a distribution map. The research results indicate that HIS can be used for the detection and visualization of the distribution of TN content in soil.

In [8] the soil test report values are used to classify several significant soil features like village wise soil fertility indices of Available Phosphorus (P), Available Potassium (K), Organic Carbon (OC) and Boron (B), as well as the parameter Soil Reaction (pH). The classification and prediction of the village wise soil parameters aids in reducing wasteful expenditure on fertilizer inputs, increase profitability, save the time of chemical soil analysis experts, improves soil health and environmental quality. These five classification problems are solved using the fast learning classification technique known as Extreme Learning Machine (ELM) with different activation functions like Gaussian radial basis, sine-squared, hyperbolic tangent, triangular basis, and hard limit. After the performance analysis of ELMs with diverse activation functions for these soil parameter classifications, the Gaussian radial basis function attains the maximum performance for four out of five problems, which goes above 80% in most of the accuracy rate calculations in every problem, followed by hyperbolic tangent, hard limit, triangular basis, and sine-squared. However, the performance of the final classification problem, i.e. the pH classification, gives moderate values with the Gaussian radial basis and best performance (near 90%), with the hyperbolic tangent.

In [9] authors determined these data at the long-term N fertilization site Mer Bleue bog, Ontario, during a two month period in summer. Soil temperatures decreased with NPK addition in shallow peat soil primarily during the daytime (t-test, $p < 0.05$) owing to increased shading, whereas they increased in deeper peat soil (t-test, $p < 0.05$), probably by enhanced thermal conductivity. These effects were confirmed by RMANOVA, which also suggested an influence of volumetric water contents as co-variable on soil temperature and vice versa ($p < 0.05$). Averaged over all fertilized treatments, the mean soil temperatures at 5 cm depth decreased by 1.3 and by 4.7 C (standard deviation 0.9 C) at noon. Water content was most strongly affected by within-plot spatial heterogeneity but also responded to both N and PK load according to RMANOVA ($p < 0.05$). Overall, water content and CO_2 concentrations in the near-surface peat (t-test, $p < 0.05$) were lower with increasing N load, suggesting more rapid soil gas exchange. The results thus suggest that changes in bog ecosystem structure with N deposition have significant ramifications for physical parameters that in turn control biogeochemical processes.

In [10] modeling and efficient nutrient management were used to evaluate turf loss problem. A three-factor and five-level central composite rotatable design (CCRD) with a simulation of a regression model was used to optimize fertilization rates. The study investigated the combined effects of fertilization with nitrogen (N), phosphorus (P), and potassium (K) on both the morphological and physiological attributes and on the integrated turf performance (ITP) of overseeded perennial ryegrass (Lolium perenne). Fertilization with N and P significantly increased turf height, density, color, fresh and dry weights, while N, P, and K significantly affected turf cover, quality and winter-kill. The Spring transition was delayed by fertilization with N and P, and accelerated by fertilization with K. Photosynthesis (Pn), transpiration (Tr), and stomatal conductance (Gs) were considerably enhanced by fertilization with N, P, and K. Protein levels and total chlorophyll levels were substantially increased by fertilization with N and P and with N, P, and K, respectively, during a 2-year period. During two separate experiments conducted during 2 consecutive years, the optimal combinations of N, P, and K were N: 30, P: 24, K: 9, and N: 30, P: 27, K: 6 g m^{-2}. The major conclusion of the paper is that a balanced nutrient application utilizing N, P, and K is key to enhancing the winter performance of perennial ryegrass.

In [11] authors emphasized that soil testing is complementary to plant tissue testing and not a substitute in orchard management. Considerations to ensure soil testing provides representative and useful information and interpretation of two common soil test parameters: 1) Saturation Percentage (SP); and 2) pH were also discussed. This article will focus on the nutrients nitrogen (N), phosphorus (P), and potassium (K).

In [12] have given method to accurately, rapidly, stably, and nondestructively measure the NPK levels in tomato plants, a nondestructive determination method based on multispectral three-dimensional (3D) imaging was proposed. Multiview RGB-D images and multispectral images were synchronously collected, and the plant multispectral reflectance was registered to the depth coordinates according to Fourier transform principles. Based on the Kinect sensor pose estimation and self-calibration, the unified transformation of the multi-view point cloud coordinate system was realized. Finally, the iterative closest point (ICP) algorithm was used for the precise registration of multi-view point clouds and the reconstruction of plant multispectral 3D point cloud models. Using the normalized grayscale similarity coefficient, the degree of spectral overlap, and the Hausdorf distance set, the accuracy of the reconstructed multispectral 3D point clouds was quantitatively evaluated. The results indicated that the multispectral reflectance could be registered to the Kinect depth coordinates accurately based on the Fourier transform principles, the reconstruction accuracy of the multispectral 3D point cloud model met the model reconstruction needs of tomato plants. Using back-propagation artificial neural network (BPANN), support vector machine regression (SVMR), and Gaussian process regression (GPR) methods, determination models for the NPK contents in tomato plants based on the reflectance characteristics of plant multispectral 3D point cloud models were separately constructed. The relative error (RE) of the N content by BPANN, SVMR and GPR prediction models are evaluated. The NPK contents determination performance of these models were more stable than those of single-view models.

In [13], authors speak about N and P use efficiency and how they are necessary for plant and environment. Nitrogen (N) and phosphorus (P) are the most important nutrients for crop production. The N contributes to the structural component, generic, and metabolic compounds in a plant cell. N is mainly an essential part of chlorophyll, the compound in the plants that is responsible for photosynthesis process. The plant can get its available nitrogen from the soil by mineralizing organic materials, fixed-N by bacteria, and nitrogen can be released from plant as residue decay. Soil minerals do not release an enough amount of nitrogen to support plant; therefore, fertilizing is necessary for high production. Phosphorous contributes in the complex of the nucleic acid structure of plants. The nucleic acid is essential in protein synthesis regulation; therefore, P is important in cell division and development of new plant tissue. P is one of the 17 essential nutrients for plant growth and related to complex energy transformations in the plant. In the past, growth in production and productivity of crops relied heavily on high-dose application of N and P fertilizers. However, continue adding those chemical fertilizers over time has bad results in diminishing returns regarding no improvement in crop productivity. Applying high doses of chemical fertilizers is a major factor in the climate change in terms of nitrous oxide gas as one of the greenhouse gas and eutrophication that happens because of P pollution in water streams.

In [14] authors provided study which shows that, complete combinations of either original reflectance or first-order derivative spectra have been developed to quantify leaf nitrogen (N), phosphorus (P), and potassium (K) contents of tree, shrub, and grass species using hyper spectral datasets from light, moderate, and severely degraded vegetation sites in Helin County, China. Leaf N, P, and K contents were correlated to identify suitable combinations. The most effective combinations were those of reflectance difference (Dij), normalized differences (ND), first-order derivative (FD), and first-order derivative difference (FD(D)). Linear regression analysis was used to further optimize sensitive band-based combinations, which were compared with 43 frequently used empirical spectral indices. The proposed hyper spectral indices were shown to effectively quantify leaf N, P, and K confirming that hyper spectral data can be potentially used for fine scale monitoring of degraded vegetation.

In [15] authors identified rapid soil and plant nutrient testing technologies based on a web search, and evaluated the basis for deploying them as alternative nutrient analytical systems. Thirty six of such applications were identified, out of which only 5 are dedicated solely to plant analysis. Collectively, the functioning mechanisms of most of the products were found to be based on colorimetry, spectroscopy or sensor technology. However, in comparison with traditional wet chemistry methods, the accuracy of the products is yet to be fully resolved, given the paucity of data in that regard. Subsequently, authors reflected upon the effectiveness of the products in generating relevant information to guide rationale fertilizer recommendations, and in that context discussed the concept of balanced fertilizer regimes that consider soil levels of different nutrients; associated soil factors that determine nutrient bioavailability and actual uptake by crops; and complex farming systems that may undermine the precision and efficiency of fertilizer application.

In [16] authors provided the study which explored the possibility of estimating nitrogen content in a pasture grass using thermal images and artificial neural networks (ANN), based on the premise that plant herbage with a higher N content would be absorbing more light energy for active photosynthesis, therefore emitting excess energy as heat. This is the first reported study to use thermal infrared images and ANN to estimate pasture nitrogen content under different conditions of nitrogen (N) fertilizer. The research was conducted in a controlled climate environment to isolate the effect of a key environmental parameter, available soil N, on pasture grass herbage temperatures. The project was the first step towards developing a smart fertilizer spreader to manage N applications based on plant temperature.

In [17] authors introduced a GA-BPNN method, which combined a back propagation neural network (BPNN) with the genetic algorithm optimization (GA). This study was conducted in Guangdong, China, based on soil nutrient contents and hyper spectral data. The prediction accuracies from a partial least squares regression (PLSR), BPNN and GA-BPNN were compared using field observations. The results showed that (1) Among three methods, the GA-BPNN provided the most accurate estimates of soil total nitrogen (TN), total phosphorus (TP) and total potassium (TK) contents; (2) Compared with the BPNN models, the GA-BPNN models significantly improved the estimation accuracies of the soil nutrient contents by decreasing the relative root mean square error (RRMSE) values at the regional scale for TN, TP and TK, respectively. This indicated that by optimizing the parameters of BPNN, the GA-BPNN provided greater potential to improving the estimation; and (3) Soil TK content could be more accurately mapped by the GA-BPNN method using HuanJing-1A Hyperspectral Imager (HJ-1A HSI) (manufacturer: China Aerospace Science and Technology Corporation; Beijing, China) The research results provided an important reference for high-accuracy prediction of soil nutrient contents.

In [18] authors provided study to assess the potential of infrared thermography (IRT) sensing by monitoring soil surface temperature (SST) with a high spatiotemporal and thermal resolution in a scalable agricultural application. Authors monitored soil surface temperature (SST) variations over a 48 h period for three treatments in a vineyard: bare soil (plot S), 100% biochar cover (plot B), and biochar-amended topsoil (plot SB). The SST of all plots was monitored at 30 min intervals with a tripod-mounted IR thermal camera. The soil temperature at 10 cm depth in the S and SB plots was monitored continuously with a 5 min resolution probe. Plot B had greater daily SST variations, reached a higher daily temperature peak relative to the other plots, and showed a faster rate of T increase during the day. However, on both days, the SST of plot B dipped below that of the control treatment (plot S) and biochar-amended soil (plot SB) from about 18:00 onward and throughout the night. The diurnal patterns/variations in the IRT-measured SSTs were closely related to those in the soil temperature at a 10 cm depth, confirming that biochar-amended soils showed lower thermal inertia than the unamended soil. The experiment provided interesting insights into SST variations at a local scale.

In [19] authors show study to examine the potential benefits of thermal imaging on farming, data were compiled from existing research on thermal imaging and analysis of soil composition in order to create a table with a color scheme as a guideline for analyzing the condition of soil. The results show that thermal imaging can detect water composition and measure the temperature of soil; this can allow farmers to determine the optimum temperature and water composition for organisms that favor fertile soil. The color scheme acts as an easy reference and effective tool for gauging soil characteristics/composition. Therefore, thermal imaging, with its easy use, has enough potential to be utilized widely throughout agriculture to check soil fertility.

In [20] Spatial predictions of soil macro and micro-nutrient content across Sub-Saharan Africa at 250 m spatial resolution and for 0–30 cm depth interval are presented. Predictions were produced for 15 target nutrients: organic carbon (C) and total (organic) nitrogen (N), total phosphorus (P), and extractable—phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), sodium (Na), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), aluminum (Al) and boron (B). Model training was performed using soil samples from ca. 59,000 locations (a compilation of soil samples from the AfSIS, EthioSIS, One Acre Fund, VitalSigns and legacy soil data) and an extensive stack of remote sensing covariates in addition to landform, lithologic and land cover maps. An ensemble model was then created for each nutrient from two machine learning algorithm.

In [21] authors analyzed the Blue-green fluorescence (BGF) emission by leaves of healthy sunflower plantlets, and implemented BGF and thermal imaging in the detection of the infection by O. cumana during underground parasite development. Increases in BGF emission were observed in leaf pairs of healthy sunflowers during their development. Lower BGF was consistently detected in parasitized plants throughout leaf expansion and low pigment concentration was detected at final time, supporting the interpretation of a decrease in secondary metabolites upon infection. Parasite-induced stomatal closure and transpiration reduction were suggested by warmer leaves of inoculated sunflowers throughout the experiment. BGF imaging and thermography could be implemented for fast screening of sunflower breeding material. Both techniques are valuable approaches to assess the processes by which O. cumana alters physiology (secondary metabolism and photosynthesis) of sunflower.

In [22] exploratory study aimed at evaluating the potential of using infrared thermography for mapping macro-porosity at the soil surface and estimating the number and size of such macropores. The presented technique was applied to a small scale study (laboratory soil flume).

In [23] authors have mentioned that Spectroscopic techniques are among the ones most utilized for this purpose and near infrared spectroscopy is the most convenient method so far. Authors show that a discrete wavelength near infrared spectroscopic device is developed and tested. Calibration is done using partial least squares regression method. The on-field testing versus laboratory testing shows a high value of coefficient of determination.

In [24] authors have analyzed effect of temperature on phosphorus content of the soil. The changes of various components of phosphorus under different thermal radiation temperature, choosing soil of protective farmland, by means of indoor thermal radiation simulation, soil was exposed under various high temperatures ranging from 100 ℃ to 700 ℃, the results showed that thermal radiation had little effect on total phosphorus and available phosphorus significantly increased between 200-300 ℃. As thermal radiation temperature was increased, water-soluble and loosely combined phosphorus content had a trend of first increase then decrease, reached the maximum at 300℃. Iron (Fe) P content and calcium (Ca) P content generally increased, aluminum (Al) P content and occluded (O) P content basically decreased. Under the radiation temperature between 100 ℃ and 400 ℃, the soil organic phosphorus translated into inorganic phosphorus, Al-P and occluded P translated into water-soluble and loosely combined phosphorus and Ca-P. Under the radiation temperature between 400℃ and 700℃, the Water-soluble and loose-bound phosphorus and Al-P translated into Fe-P, Ca-P and occluded P. Comprehensive analysis, 200-300℃ was favorable when soil sterilization applied with thermal radiation.

In [25] authors investigated the potential of the infrared spectroscopy technique for non-destructive measurement of soil properties. For the study, 280 soil samples were collected from several regions in Zhejiang, China. Data from near infrared (NIR, 800–2500 nm), mid infrared (MIR, 4000–400 cm–1), and the combined NIR–MIR regions were compared to determine which produced the best prediction of soil properties. Least-squares support vector machines (LS-SVM) were applied to construct calibration models for soil properties such as available nitrogen (N), phosphorus (P), and potassium (K). The results showed that both spectral regions contained substantial information on N, P, and K in the soils studied, and the combined NIR–MIR region did a little worse than either the NIR or MIR region. This work demonstrated the potential of LS-SVM coupled to infrared reflectance spectroscopy for more efficient soil analysis and the acquisition of soil information.

In [26], authors have given featured Application of quantitative models for visible near-infrared ray spectroscopy for the measurement of soil-available potassium. These results show that the predictors of soil-available potassium exhibit different influences with 29 pretreatment methods and eight regression algorithms. Authors found that a combination of three methods, Savitzky–Golay, standard normal variate, and dislodge tendency, had better stability than other pretreatment methods. The boosting algorithms that form an ensemble of multiple weak predictors have better accuracy and stability than other regression algorithms. Therefore, a more robust and trustworthy visible near-infrared ray (VIS-NIR) model is proposed, which can be used across industries to quantify the soil-available potassium concentration.

In [27] a review is provide which sums up the application of photo acoustic and photo thermal spectroscopies for the analysis and characterization of soils and soil organic matter and discusses the outlooks in this area.

In [28], authors have given method for measuring the NPK levels in tomato plants, a nondestructive determination method based on multispectral three-dimensional (3D) imaging was proposed. Multiview RGB-D images and multispectral images were synchronously collected, and the plant multispectral reflectance was registered to the depth coordinates according to Fourier transform principles. Based on the Kinect sensor pose estimation and self-calibration, the unified transformation of the multiview point cloud coordinate system was realized. Finally, the iterative closest point (ICP) algorithm was used for the precise registration of multiview point clouds and the reconstruction of plant multispectral 3D point cloud models. Using the normalized grayscale similarity coefficient, the degree of spectral overlap, and the Hausdorff distance set. The results indicated that the multispectral reflectance could be registered to the Kinect depth coordinates accurately based on the Fourier transform principles, the reconstruction accuracy of the multispectral 3D point cloud model met the model reconstruction needs of tomato plants. Using back-propagation artificial neural network (BPANN), support vector machine regression (SVMR), and Gaussian process regression (GPR) methods, determination models for the NPK contents in tomato plants based on the reflectance characteristics of plant multispectral 3D point cloud models were separately constructed. The NPK contents determination performance of these models were more stable than those of single-view models.

In [29] authors compared the detection ability of laser-induced breakdown spectroscopy (LIBS) coupled with support vector regression (SVR) and obtain an accurate and reliable method for the rapid detection of all three elements. A total of 58 fertilizer samples were provided by Anhui Huilong Group. The collection of samples was divided into a calibration set (43 samples) and a prediction set (15 samples) by the Kennard–Stone (KS) method. Four different parameter optimization methods were used to construct the SVR calibration models by element concentration and the intensity of characteristic line variables, namely the traditional grid search method (GSM), genetic algorithm (GA), particle swarm optimization (PSO), and least squares (LS). The training time, determination coefficient, and the root-mean-square error for all parameter optimization methods were analyzed. The results indicated that the LIBS technique coupled with the least squares–support vector regression (LS-SVR) method could be a reliable and accurate method in the quantitative determination of N, P, and K elements in complex matrix like compound fertilizers.

In [30] authors presented a detailed analysis of nutrient flows and losses in the “feed intake excretion housing storage treatment application” manure-chain, while considering differences between livestock production systems. Authors estimated the environmental loss from the manure-chain in 2010 to be up to 78% of the excreted nitrogen, and over 50% of excreted phosphorus and potassium. Greatest losses occurred from housing and storage stages, via NH3 emissions (39% of total nitrogen losses), and direct discharge of manure to water bodies or landfill (30-73% of total nutrient losses).

In [31] authors explored the possibility of estimating nitrogen content in a pasture grass using thermal images and artificial neural networks (ANN), based on the premise that plant herbage with a higher N content would be absorbing more light energy for active photosynthesis, therefore emitting excess energy as heat. This is the first reported study to use thermal infrared images and ANN to estimate pasture nitrogen content under different conditions of nitrogen (N) fertiliser. The research was conducted in a controlled climate environment to isolate the effect of a key environmental parameter, available soil N, on pasture grass herbage temperatures. The project was the first step towards developing a smart fertilizer spreader to manage N applications based on plant temperature.Image fusion is in its infancy in the application of Digital Soil Mapping, and the incorporation of the image pan sharpened spectral indices into the soil prediction models has seldom been analyzed. This research performed image pan sharpening of Landsat 8, WorldView-2, and Pleiades-1A in a smallholder village called Masuti in South India using three pan sharpening techniques: Brovey, Gram-Schmit (GS), and Intensity-Hue-Saturation (IHS) methods. The research analyzed the relationships between multispectral (MS) and pan sharpened (PAN) spectral indices and soil total nitrogen (TN), developed the soil TN prediction models using Random Forest methods, and explored the effects of different PAN spectral indices on soil TN prediction models. The results showed the spectral behavior of PAN spectral indices and MS spectral indices were similar. The results also demonstrated that soil TN models based on MS/PAN spectral indices have slightly higher model performance and more detailed characterization of TN spatial pattern compared with soil TN models based on MS spectral indices. Soil TN models based on the GS PAN and MS spectral indices attained slightly higher prediction accuracy compared with those based on other PAN and MS spectral indices. This research advocates the promotion of image pan sharpening techniques in digital soil mapping and soil nutrient management research.

III. CONCLUSION

Soil testing plays important role for selecting right crop to be cultivated in the farm field. The right economic approach starts from testing the soil contents and respective changes with respect to time in the soil as per consumption and age of the crops. The nutrient content analysis of the soil is important aspect and this paper contributes to form a platform for understanding the soil testing methods for analyzing its nutrient contents.

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