Selection of Best Frequency Range for Soil Urea Prediction

Sulaxana R.Vernekar, Jivan S. Parab

Abstract: Soil is a complex system and its nature determines the types of crops that can be cultivated. Soil testing plays an important role in determining its ability to grow crops. Conventional soil testing methods are found to be cumbersome and expensive and also time consuming. Hence there is a need for methods which can give fast results and help in effective crop cultivation. Soil exhibits both spatial and temporal variability. The traditional methods of soil testing do not take into account the variability of the soil and uniform application of external inputs is done. This leads to over or under use of fertilizers, which in turn results into soil turning infertile, ground water getting contaminated etc. Precision Farming technique makes use of new technologies to take into consideration the variability exhibited by soil and is also called as site specific management. Soil nutrient testing is an important aspect of soil testing which helps in finding out the available soil nutrients and which in turn determines the crops that can be cultivated. Various techniques have been developed to determine the soil nutrients but most of these techniques are found to be time consuming. Hence there is a need to develop techniques which can give real time measurements of soil nutrients. This paper discusses about the use of RF spectra for predicting the soil nutrients. The RF spectra are obtained using a cell which is designed based on the principle of dielectricity. Samples were prepared in the laboratory by mixing five different components namely urea, potash, phosphate, lime and salt in distilled water. RF spectra of different samples having varying concentrations of the components were recorded. Multivariate analysis based on the Partial Least Square Regression technique was used to predict the amount of urea in a sample. The prediction of urea was done using two different frequency ranges i.e 10MHz-500MHz and 500MHz – 1000MHz and analysis of the results was done to determine which frequency range gives better results. The results show that percentage error of urea prediction is better in the frequency range of 500MHz-1000MHz as compared to 10MHz-500MHz.

Keywords: RF, Urea, PLSR, Multivariate.

I. INTRODUCTION

The impact of climate change, growing global population and the limited resources available for food production has put forth challenges in the field of agriculture. There is a need to increase the agricultural output in a sustainable manner[1] without having any adverse effects on the environment. The Green revolution made it possible to increase crop production by using chemical fertilizers. It is expected as per the FAO report[2] that the demand for fertilizers is expected to grow by 1.9% annually and by the end of 2020 is expected to reach 201.66 million tonnes. Soil being a very complex system exhibits both spatial and temporal variability. Thus the uniform use of fertilizers in a farm may not necessarily increase the crop production [3]. Hence there is a need to use techniques that take into account the complex nature of soil. Precision Farming also known as site specific management techniques are widely used in developed nations which make use of different sensors for soil measurements and accordingly adjust the application of external inputs to the soil. Precision farming techniques are technology driven and use high end equipments. These techniques are found to be profitable when used on large areas [4]. Soil nutrient sensing forms an important aspect in precision farming since it provides information on the application of external fertilizers to manage crop production. Various soil nutrient sensing methods have been developed and are commercially available while some of the techniques still under development [5]. Since soil nutrient sensing is both site and time specific there is a need to develop techniques that are rapid, precise and accurate so that proper monitoring of soil and crop growth can be done. This paper discusses a new approach of using RF spectra for soil urea prediction with an objective of developing a smart, rapid low cost soil monitoring system. Two different frequency ranges of 10MHz-500MHz and 500MHz-1000MHz are used for predicting the amount of urea present in a sample and a comparative analysis is done to find out which frequency range gives better results.

II. EXPERIMENTAL SETUP

The sensor for recording the RF spectra of the soil components is designed on the principle of dielectricity. The detail design of the cell is discussed in [6]. The samples were prepared in laboratory by making a mixture of five different components namely urea, potash, phosphate, lime and salt in distilled water. The capacity of the cell was 15 ml and accordingly molar solutions of all the above components were prepared. For 15ml of water the amount of urea to be added was found to be 225mg. Similarly the amount for the other components was found and this concentration was denoted as normal or 1 in the study. Other concentrations which were used in the study were denoted as 0.5 for half of the normal, 0.75 for three fourth of the normal and so on. The details denoting the concentrations are as given in Table 1.

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Table 1: Concentrations denotation table

Concentrations denotation	Concentration(mg/15ml)				
	Urea	Potash	Phosphate	Lime	Salt
0.5	112.5	139.7	1890	187.5	109.87
1	225	279.5	3780	375	219.75
1.5	337.5	419.2	5670	562.5	329.63
2	450	548	7560	750	439.5
3	675	687.5	9450	1125	659.25

III. METHODOLOGY

Signal Hound tracking generator USB-TG44A and a Signal Hound spectrum analyzer USB-SA124B were connected to the cell to form a scalar spectrum analyzer. The samples were placed in the cell and RF spectra of the sample were recorded using the spectrum analyzer. The recorded spectra correspond to the dielectric loss in the cell due to the molecular vibrations in the sample. These spectra were then passed into a multivariate system based on Partial Least Square Regression Technique. PLSR is a technique widely used in analysing spectroscopic data. PLSR builds a linear model represented as Y=XB+E where X is the set of spectra and Y is the set of components or quantities that are to be predicted[7].The study used ParLe's software developed by R. A. Viscarra Rossel [8] as the PLSR tool.

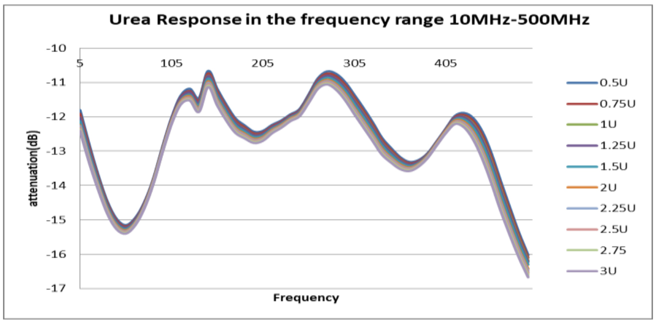

Fig.1: Response of urea from 10MHz-500MHz.

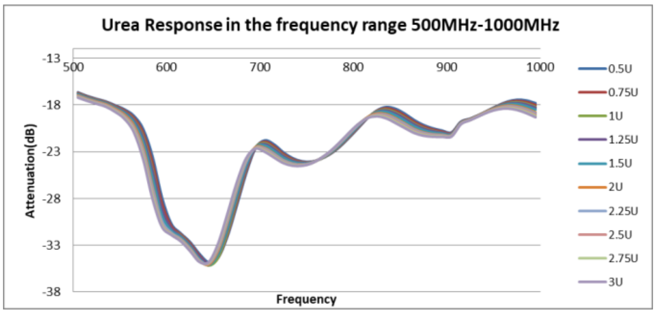

Fig.2: Response of urea from 500MHz-1000MHz

Fig.1 & Fig.2 above show the frequency response of urea in the frequency ranges of 10MHz-500MHz and 500MHz-1000MHz. Samples are prepared by mixing different concentrations of the components taken in the study. RF responses for each of the sample are recorded. 16 samples have been used to train the PLSR model. The RF spectra for the 16 samples are as shown in Fig. 3. and Fig.4 for the frequency ranges 10MHz-500MHz and 500MHz-1000MHz.

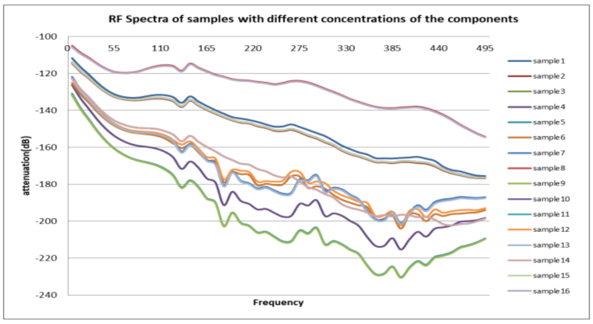

Fig.3: RF Spectra of 16 samples used to train the PLSR model for 10MHz-500MHz

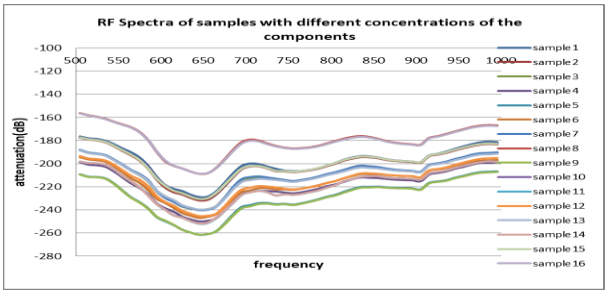

Fig.4: RF Spectra of 16 samples used to train the PLSR model for 500MHz-1000MHz.

IV. RESULTS AND DISCUSSIONS

For the prediction of the concentration of urea in a sample, the test samples were prepared by varying the concentration of urea ranging from 0.5 to 3 and keeping the concentration of all other components in the sample at their normal value i.e 1.

The RF spectra for each of these samples in the frequency range of 10MHz-500MHz and 500MHz-1000MHz were recorded and then used to predict the concentration of urea in that sample. Analysis of the predicted values of urea was done to find out which frequency range gives better prediction of urea in a sample. The results obtained are as tabulated in Table 2 .

Table 2: Results of Urea prediction in the frequency range of 10MHz-500MHz and 500MHz-1000MHz

Urea_ conc	Actual Urea (mg/15ml)	Predicted Urea		% rate of Error	
		10MHz-500MHz	500MHz-1000MHz	10MHz-500MHz	500MHz-1000MHz
0.5	112.5	111.25	119.94	1.11	6.61
0.75	168.75	167.91	168.75	0.49	0.0
1	225	225.04	225	0.017	0.0
1.25	281.25	281.51	281.25	0.092	0.0
1.5	337.5	338.18	337.5	0.2	0.0
2	450	451.77	450.04	0.39	0.008
2.5	562.5	540.91	545.75	3.84	2.97
3	675	630.03	641.47	6.66	4.93

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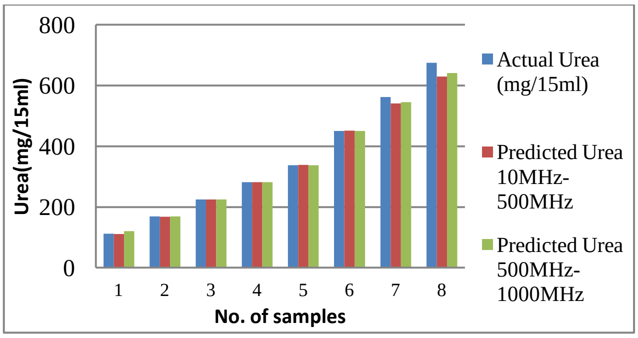

Fig.5: Chart showing urea prediction .

Table 2 shows the results of urea prediction in the frequency range of 10MHz-500MHz and 500MHz-1000MHz. Results indicate that percentage error rates in the prediction of urea are better in the frequency range of 500MHz-1000MHz as compared to the frequency range of 10MHz-500MHz. The percentage error rates in the prediction of urea in the 500MHz-1000MHz show zero percent error rates for four concentrations of urea corresponding to 0.75, 1, 1.25 and 1.5 which is not the case for 10MHz-500MHz. Fig.5 shows a chart which indicates the actual amount of urea in a sample and the predicted values of urea in that sample for the two frequency ranges taken in the study.

V. CONCLUSION

The percentage error rates are found to be much lower in the frequency range of 500MHz-1000MHz as compared to 10MHz-500MHz. The prediction of urea concentration close to the normal concentration gives 0 percent error rates and as we increase the concentration above 1.5 and below 0.75 the error rates are found to increasing, but by much smaller percentages in the frequency range of 500MHz-1000MHz as compared to the 10MHz-500MHz frequency. Hence a system can be developed for recording RF spectra in the frequency range of 500MHz-1000MHz for the prediction of soil urea content. A similar study can be performed to predict the values of other components present in the sample and find the frequency range that is best suitable for prediction of each of the component that is considered in the study.

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Sulaxana R. Vernekar, has completed Ph.D. in Electronics at Goa Universityin June 2016. She is Assistant Professor in the Department of Computer Science at GVM's GGPR College of Commerce, Ponda-Goa and has 23 years of teaching experience. She has participated in number of symposium / workshops and presented her research work. Her areas of interest are agricultural electronics, micro electronics and digital signal processing.

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