The Andhra Agric. J 65 (spl): 1-6*, 2018*

A DGPS Based on-the-go Soil Nutrient Mapping System: A Review

R K Sahni, D Kumar, P S Tiwari, V Kumar, S P Kumar and N S Chandel
Agricultural Mechanization Division, ICAR-CIAE, Bhopal.

ABSTRACT

Sensor technology along with advanced equipment improves the ability for input efficient farming in the environment friendly way.The ultimate goal of sensortechnology in agriculture is to enable farmers and farm managers to analyse variations in field conditions across the growing season. Soil sensing techniques to assess are being developed as an alternative to tedious manual soil sampling and laboratory testing. A tractormounted sampler collects a required quantity of soil sample from the field and automatically transfer it for analysis.Major soil nutrient/ properties such as N, P, K, Na, pH etc. measurement with specific site can be done by using ISE &VNIRreflectance spectroscopy with the help of DGPS tracking system to measure the accurate site location to collect samples. The site specific soil nutrient value can be recorded in the computer. A DGPSbased on-the-go soil nutrient measurement system measuresthe soil nutrient in real time. The proposed system will have capability to store sample location & nutrient properties of soil, so that the data can be analysed for variable rate fertilizer application.

Keywords: *soil nutrient mapping, Ion selective electrode (ISE), Soil sensor, Soil spectroscopy, DGPS.*

Technological change has been the major driving force for increasing agricultural productivity and promoting agriculture development in developing countries. In the past, the choice oftechnologies and their adoption has been one of the major factorsto increase production, productivity and farm incomes. Sensor technology along with advanced equipment improves the ability for input efficient farming in the environment friendly way. Sensors can improve on the conventional methods used to deriveagronomic recommendations. Compared to the conventional approach,sensors based technology provide rapid and reproducible measurements of soil at fieldcondition, they provide a cheaper alternative that avoid the problemsimposed by time-consuming sparse sampling, sample transportationand preparation, and elaborate laboratory analyses. Sensors based technology providefarmerswith effective tools for strategic on-farm testing to check conditionsat critical stages in the growing season at different locations intheir fields. Farmers can use sensed data tobuild site-specific databases that relate soil nutrient concentrations toplant reaction and crop development during the growing season, andultimately to yield. Although this might take some time, this approachis more desirable than usingthe highly generalized generic data of theconventional procedures.Sensors can help in fine-tuning the soil nutrientmanagement according to soil variability, so asto balance productionwith environmental quality, including the conservationof soil. The global positioning system (GPS) receivers, used to locate and navigate agricultural vehicles within a field, have become the most common sensor in precision agriculture. When a GPS receiver and a data logger are used to record the position of each soil sampleor measurement, a spatial map can be generated and processed along with other layers of variable information.On theother hand, some soil sensors may be used to vary application rates in response to sensoroutput in real time without a GPS receiver (Morgan and Ess, 1997).

The soil macronutrients, nitrogen (N), phosphorus (P), andpotassium (K), are essential elements for crop growth. Other ingredients are either micro-nutrients (e.g., Fe, S, Mn, Zn) orinert carrier materials.Theapplication of commercial N, P, and K fertilizers has contributedto a tremendous increase in yields of agricultural crops. However, excessive use of hese fertilizershas been a source of contamination for surface andgroundwater. Ideally, application rates should be adjustedbased on estimates of the requirements for optimum productionat each location because there is high spatial variability of N, P,and K within individual agricultural fields.While developments in precision agriculture and site-specific management procedures have made significant in-roads on these issues, and many researchers have developed effective means to determine soil properties such as texture, organic matter, salinity, compaction characteristics, and in-situpH , routinely obtaining localized on-the-go measurements of N, P, and K that are reliable enough to drive effective fertilizer application remains a challenge.

For any on-the-go soil sensor to be successful there is a need to perform at least five key functions (Fig. 1):

a) Initializing the system: Prepare on-the-go system for a measurement, ensuring that all components are ready for use and free of any residual influence from previous measurements.

b) Sampling the soil: Permit periodic or continuous contact with the soil and/or repeatedly and reliably obtain soil samples.

c) Deriving the sample volumes: Reliably derive soil samples and/or extracts of a controlled volume/mass.

d) Presenting the sample: Present known volume/mass of soil/soil extract in effective range of the sensor.

e) Performing a measurement: Accurately and/or precisely (with calibration) assess ion concentrations.

These processes must be repeated for subsequent measurements.

In this study different approach for on-the-go measurement of soil nutrientshas been reviewed and proposed a robust system for on-the-go soil nutrients/propertiesmeasuring system.

Spatially dense soil sampling is required to produce representative maps of soil chemical properties suitable for taking advantage of site-specific crop management. The economically feasible density of soil sampling and the uncertainties associated with interpolation methods limit the potential for conventional (manual) soil sampling. Higher resolution maps could significantly decrease overall estimation errors and result in higher potential profitability of variable rate soil treatment (Pierce and Nowak, 1999).

For soil sample collection Schickendanz *et al*., (1973), Chandler and Savage (1979), and White (1982) all describe hydraulically activated coring devices mounted to either front,side, or rear of a tractor. These devices all collect undisturbed individual core samples, but the tractor must be stopped, their sampling rates are low, and they often eject incomplete cores. Wrenn *et al*., (1982) describes a tractormounted sampler that collects a core and releases it on the ground for manual collection. None of the devices have any mechanism for automatically transferring the samples onward for analysisas is required for automated on the go soil analysis. Devices for collecting continuous samples consist of rotating tines (Johnson, 1981), subsoilertype blades with elevators (Behringer, 1982), slotted disks and powered augers (Sneath *et al*., 1989), and chain cutters (Sneath *et al*., 1989; Adsett, 1990). These devices generally sample the 30 to 100 cm zone, have high draft requirements (45 to 75 kW), have problems with clogging in wet and clayey soils, are susceptible to stone damage, or jamming due to silicates glazing from heat generation during sampling, or have problems coping with surface trash.GPS equipped, auger type system enables automatic control of precise depth under varying field conditions while collecting soil samples. The system was reported to work well. However, like the coring devices, it must also stop at each sampling location, and soil is collected in a container for later analysis (Adamchuk *et al*.,2002).

Numerous on-the-go techniques were developed to measure soil properties (Adamchuk *et al*., 2004). Direct electrochemical measurement of soil chemical properties, including pH, soluble potassium, and residual nitrate contents, has been the subject of several investigations. Ion-selective electrode (ISE) and ion-selective field effect transistor (ISFET) technologies have been the means for measuring the activity of selected ions in aquatic solutions. In both cases, the output signal is related to the difference in electrical potential between the ion-selective membrane (e.g., glass, PVC, etc.) and a reference (Talibudeen, 1991; Artigas *et al*., 2001).

Birrell and Hummel (2001) investigated the use of a multi-ISFET sensor chip to measure soil nitrate in a flow injection analysis (FIA) system using low flow rates, short injection times, and rapid rinsing. The multi-ISFET/FIA system was used to measure soil nitrate content in manually prepared soil extracts (R^2> 0.90) under controlled conditions. The potential of several PVC matrix membranes for use as ISFET membranes for soil nitrate measurement was investigated by Birrell and Hummel (2000).

Kataoka *et al*.,(2004) developed an on the go soil sampling system that consists of three parts roto-tiller, soil transport conveyor, and soil can collection apparatus (Fig. 2). As the tractor moves forward, the roto-tiller throws pulverized soil rearward onto a flighted plastic soil transport conveyor, which subsequently dumps the soil into cans being moved transversely beneath its outlet end with a typical canning factory type round belt conveyor. Sampling depth is up to 20 cm. Sampling location is recorded with a GPS mounted on the tractor. The system was reported to have good performance in generating pulverized soil. However, there were issues with the soil conveyer becoming blocked because too much soil was thrown onto the conveyor be adequately handled at certain conveyor speeds. The study was conducted to understand the performance of the system at various combinations of forward travel speeds, roto tiller rotational speeds, and trans port conveyor speeds.

Sibley *et al.*, (2008) developed a soil nitrate mapping system (SNMS) that provides a way to collect the data necessary to analyze the variation in soil NO_3-N. The SNMS consists of six sub assemblies that are soil sampler sub assembly, soil metering and conveying sub assembly, nitrateextractionand measurement subassembly, auto calibration sub assembly, control subassembly, GPS assembly. The system automatically collects a soil sample at a depth of 0 to 15 cm, mixes it with water, and directly analyzes it electrochemically for nitrate concentration in real time using a nitrate ion selective electrode (NO_3 ISE) as the analysis instrument (Fig. 3).Additionally, global positioning system (GPS) geo referenced data are simultaneously recorded at each sampling location to enable a nitrate map to be created for the field. The system can be used to analyze soil samples automatically while on the go, or manually while stationary by hand placing samples into the nitrate extraction and measurement sub assembly. A portable and modified combination of the nitrate extraction and measurement subassembly, auto calibration subassembly and control subassembly used in combination with a GPS.

Sethuramasamyraja *et al.*, (2008) designed an Agitated Soil Measurement (ASM) method for mapping of soil pH, soluble potassium and residual nitrate contents using ISEs.ASM, an Integrated Agitation Chamber Module (IACM) was developed and attached to a commercial soil pH mapping implement (Fig. 4). Precision of the tested electrodes was assessed through the root mean squared error and ranged from 0.10 for pK to 0.22 for pNO_3 (units represent the negative base 10 logarithm of the molar concentration of specified ions). The accuracy of the electrodes was assessed by comparing test results against reference measurements conducted in a commercial soil laboratory using the linear regression method. Average accuracy error ranged from 0.11 for pK to 0.23 for pNO_3.ASM method was implemented using a prototype IACM developed as an attachment for a commercial on the go mapping system and evaluated in laboratory conditions. This prototype was tested with four ISEs (two combination pH, one potassium and one nitrate half-cell electrodes) while performing ASM on 15 Nebraska soils. A manually controlled laboratory experiment was conducted as the best possible implementation of the recommended ASM technique. Calibration parameters were stable during each test for pH and potassium electrodes. Results improved significantly for the manually controlled ASM laboratory experiment in Agitated soil measurement method for integrated on-the-go mapping of soil pH, potassium and nitrate contents.

Visible and near infrared (VNIR) diffuse reflectance spectroscopy has become increasingly attractive to researchers for estimating soil properties by Viscarra and Chen, (2011), due to its ability to provide rapid, cost effective measurements compared to laboratory reference methods of soil analysis.

Sudduth *et al.*,(2009)used VNIR reflectance approach to measure soil phosphorus (P) and potassium (K). The analyses of P, R^2 values ranged from 0.06 to 0.87 and RPD (the ratio of standard deviation to root mean square error) values ranged from 0.67 to 1.94. Accuracies varied by soil type, dataset size, wavelengths investigated. VNIR spectroscopy (400 - 1100 nm) and neural network analysis to investigate P and K of 41 soils from Thailand by Bogrekci& Lee (2005), obtained satisfactory results. They analyzed 114 soil samples from a 13 ha area and find that the result depended on pre-treatment and spectral resolution.

Guotian *et al.*,(2013) used different strategies to estimate soil P and K concentrations using VNIR spectral data. Soil samples from two MLRA regions in Missouri provided reasonable estimates of P and K using standard pre-treatment techniques. The most encouraging aspect of this research was with regard to pre-treatment of the spectral data. When the Direct orthogonal signal correction (DOSC) pre-treatment was applied to the P (0, 27) and K (0,192) datasets, calibration and validation results were significantly improved. Further study on the value of this pre-treatment method is clearly warranted in factors affecting soil phosphorus and potassium estimation by reflectance spectroscopy.

La *et al*. (2008) studied 37 surface soil samples from Missouri and Illinois. They compared the accuracies of P and K estimates from reflectance sensing (350 – 2500 nm), a prototype ion-selective electrode (ISE) system, and a combination of both reflectance and ISE sensing. They concluded that a PLSR model including both spectral and ISE data could provide very good results.

PROPOSED SYSTEM

The DGPS antenna will be mounted on the tractor which stores the value of coordinates of soil sampling position. The coordinate values will be saved in computer. The soil sampler unit will collect a require size of soil sample from15cm-20cm deep in the fieldand transfer it to soil analysis chamber. In the soil analysis chamber an aqueous mixture will be prepared. A stirring unit will stirfor specific time period. Once the soil mixture will be ready it will go toISE for nutrient sensing. The ISE will insert in prepared soil mixture and give the measured value by electronic meter, this nutrient value will be save in meter's internal memory as well as external computer in real timedigital format. Also the result will be displayed on screen for manual record.The soil nutrient properties will be synchronized with DGPS coordinate for future use.Figure 5 shows the block diagram of the proposed system (Fig. 6).

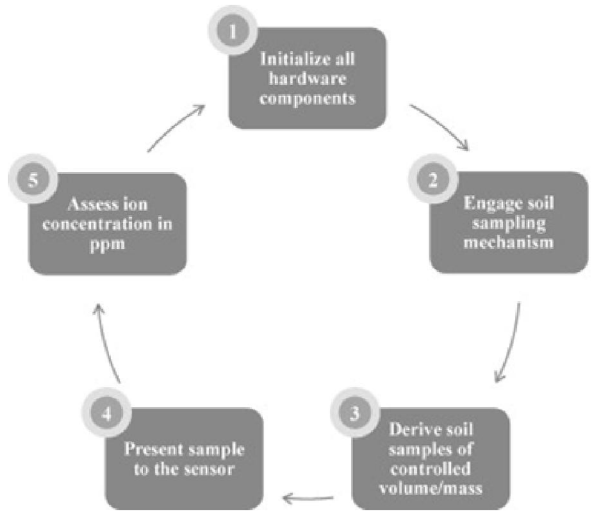

Fig. 1: Five fundamental functions of an on-the-go sensor

Fig.2: Soil sampling machine system.

(1) Soil sampler

(2) Soil metering and conveying

(3) Nitrate extraction and measurement,

(4) Auto-calibration,

Fig.3:Soil Nitrate Mapping System (SNMS)

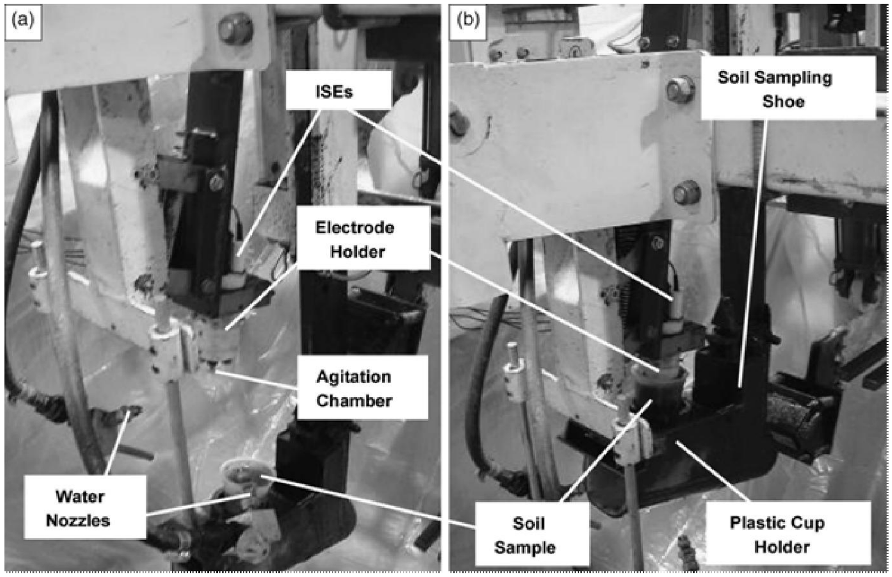

Fig.4: IACM (a) before (b) during a field simulation ASM measurement

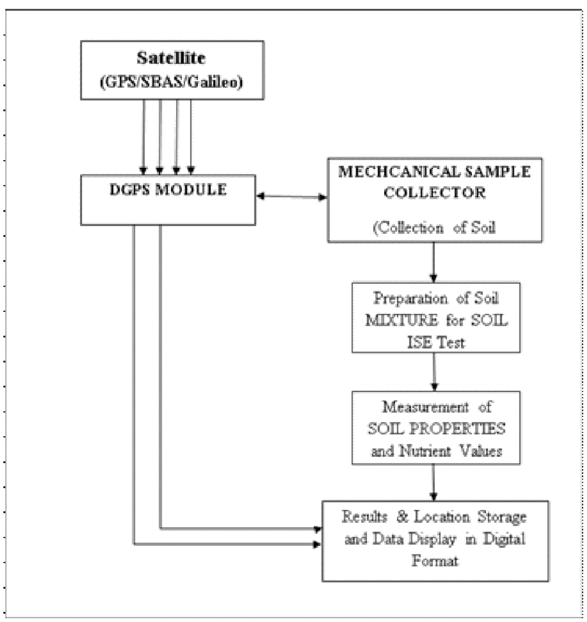

Fig. 5: Block diagram of proposed system for Soil Measurement

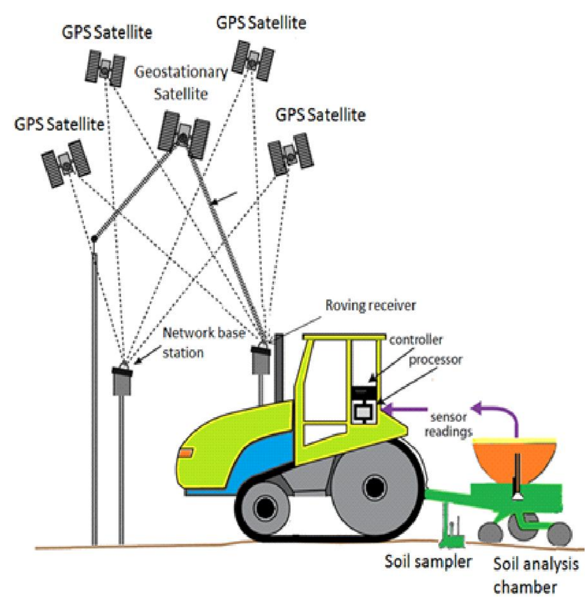

Fig. 6: Proposed DGPS based on-the-go soil nutrient measurement system

CONCLUSION

In this study, different methods for on-the-go soil samples collection and soil nutrient sensing in the fieldwere reviewed. The position of soil sample collection is mapped by GPS. On the go soil sampling system mainly consists of soil cutting unit, soil transport conveyorand soil collection apparatus. The soil nutrients are sensed by ISE & VNIR methods. Here we proposeDGPSbased on-the-go soil nutrient measurement system for measurement of the soil nutrient in real time. The proposed system will have capability to store sample location & nutrient properties of soil, so that the data can be analysed for variable rate fertilizer application.

LITERATURE CITED

Adamchuk V I, Hummel J W, Morgan M T, Upadhyaya S K, 2004 On-the-go soil sensors for precision agriculture. Comput. Electron. Agric. 44 (1), 71–91.

Adamchuk V I, Dobermann A, Morgan M T and Brouder S M 2002 Feasibility of on the go mapping of soil nitrate and potassium using ion selective electrodes. ASAE Paper No. 021183. St. Joseph, Mich.: ASAE.

Adsett J F 1990 Automated field monitoring of soil nitrate levels. Unublished PhD diss. Saskatoon, Sask.: University of

Saskatchewan, Department of Agricultural Engineering.

Artigas J, Beltran A, Jimenez C, Baldi A, Mas R, Dominguez C and Alonso J 2001 Application of ion sensitive field effect transistor based sensors to soil analysis. Comput. Electron. Agric. 31, 281–293.

Behringer P 1982 Agricultural soil sampler preventing clogging of wet soil. West German Patent No. DE 3,040,807.

Birrell S J and Hummel J W 2000. Membrane slection and ISFET configuration evaluation for soil nitrate sensing. Trans. ASAE 43 (2), 197–206.

Birrell S J and Hummel J W 2001 Real-time multi-ISFET/FIA soil analysis system with automatic sample extraction. Comput. Electron. Agric. 32 (1), 45–67.

Bogrekci I and Lee W S 2005 Spectral soil signatures and sensing phosphorus. Biosystems Engineering 92(4): 527-533.

Chandler J M and Savage K E 1979 A versatile and economic tractor mounted soil sampler. Agron. J. 71(2): 373 374.

Guotian Hu, Kenneth A, Sudduth, D. Brenton Myers, Dongjian He, Manjula V. Nathan,2013 Factors Affecting Soil Phosphorus and Potassium Estimation by Reflectance Spectroscopy, ASABE conf. 2013

Johnson G V 1981 Continuous soil sampler. U.S. Patent No.4,304,139.

Kataoka T, Saito M, Okamoto H, Hata S and Ehsani R 2004 Development of continuous soil sampling machine system. ASAE Paper No. 041047. St. Joseph, Mich.: ASAE.

La W J, Sudduth K A, Chung S O, and Kim H J 2008 Spectral reflectance estimates of surface soil physical and chemical properties. ASABE Paper No. 084242. St. Joseph, Mich.: ASABE.

Morgan M and Ess D 1997 The precision-farming guide for agriculturists. Deere and Company.

Pierce F J and Nowak P 1999 Aspects of precision agriculture. Adv.Agron. 67, 1–85.

Schickendanz D M, Onken A B, CummingsT and Jones R M 1973 A tractor mounted hydraulically operated soil sampler for rapid soil coring. Agron. J. 65(2): 339 340.

Sibley K J, Adsett J F and Struik P C 2008 An on-the-go soil sampler for an automated soil nitrate mapping system. Transactions of the ASABE, 51(6), pp.1895-1904.

Sudduth K A, Kitchen N R and Kremer R J 2009 VNIR spectroscopy estimation of soil quality indicators. ASABE Paper No.097019. St. Joseph, Mich.: ASABE.

Sneath R W, Phillips V R and Price J S 1989 Powered soil samplers for heavy metals and some concepts for the future. J. Agric. Eng. Res. 44(3): 159 174.

Sethuramasamyraja B, Adamchuk V I, Dobermann A, Marx D, Jones DD and Meyer GE 2008 "Agitated soil measurement method for integrated on-the-go mapping of soil pH, potassium and nitrate contents", Comput. Electron. Agric.60 (2),212-225

Talibudeen O 1991 Ion-selective electrodes. In: Smith, K.A. (Ed.), Soil Analysis. Modern Instrumental Techniques, second ed. Marcel Dekker, Inc., New York, New York, USA, pp. 111–182.

ViscarraRossel R A and Chen C 2011 Digitally mapping the information content of visible–near infrared spectra of surficial Australian soils. Remote Sensing of Environment 115: 1443-1455.

White R J G 1982 Backhoe mounted soil coring machine. Agron. J. 74(6): 1094 1096.

Wrenn N R, Taberner P, Pinfold J E and Retemeyer P 1982 A tractor mounted sampler for soil invertebrates. New Zealand J. Exp. Agric. 10: 225 22.