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DEVELOPMENT OF TRACTOR OPERATED REAL TIME MEASURING SYSTEM FOR MAPPING OF SPATIAL VARIATION IN SOIL pH

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Abstract: Soil pH is an important physio-chemical property representing soil characteristics and plays an important role in plant growth. Soil pH affects crop yields, plant nutrient availability and soil micro-organism activity. For small areas, measuring the spatial variation in soil pH is feasible. However for the large areas, pH determination of the multiple soil samples by using traditional method in laboratory is very tedious and time consuming. Considering the need and scope of precision agriculture in India, a real time data logging pH measuring system was developed to determine the soil pH directly in the field at specific GPS locations by integrating soil pH sensor and a GPS receiver with a portable data logger. Soil mapping was done for observing the spatial variation in soil pH using ArcGIS. The results showed that the field had variation in soil pH and the developed soil pH measuring system was capable to measure the spatial variation in soil pH. The average soil pH measured by developed soil pH measuring system in different tillage treatments varied from 7.98 to 8.18, 7.60 to 7.94 and 8.01 to 8.21, respectively.

Keywords: *soil pH measurement, pH sensor, data logger, mapping, spatial variation*

INTRODUCTION

The soil pH is an indicator of the acidity or alkalinity of soil. The measure of dissociated hydrogen ion (H^+) in the soil solution directly impacts soil acidity and

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alkalinity, as hydrogen-ion activity increases, the pH value decreases and vice versa. The pH of soil is an important physio-chemical characteristic/property because it influences crop yield, suitability of soil for crop production, availability of plant nutrients in the soil, and soil micro-organism activity which influence key soil processes. Soil pH has profound influence on the relative availability of plant nutrients, lightly acidic conditions generally considered optimal for the overall availability of both macro and micronutrients [1]. Proper soil pH increases microorganism activity which produces improved soil tilth, aeration and drainage which in turn allows better use of nutrients, increased root development and drought tolerance. In Punjab, the soil profile characteristics are influenced to a very limited extent by the topography, vegetation and parent rock and much more pronounced because of the regional climatic differences. The soil pH in 95 % of the net cultivated areas of Punjab ranged between 6.5 and 8.7 with an average pH value of 7.99 and 40 % area of Punjab have soil pH between 6.5 - 7.5 and 55 % area between pH 7.5 - 8.5 [2]. Soils in the pH range of 6.5 - 8.7 are considered as the most suitable for most of the crops [3].

Soil pH may be measured using a number of colorimetric and potentiometric techniques. For rapid determinations of soil pH, colorimetric techniques have been applied in the field. Although these estimates are relatively rapid and suitable for field use, but their precision and accuracy were lower than potentiometric methods. Potentiometric techniques are the preferred laboratory methods for measuring soil pH as they provide precise and accurate results [4]. Sensor development is expected to increase the effectiveness of precision agriculture. In particular, sensors for on-the-go measurement of soil properties have the ability to provide precise measurements at a relatively low cost [5]. The component of precision agriculture includes remote sensing, global positioning system, geographical information system, soil sensing and analysis, soil properties mapping and information. It was observed that many researchers and manufacturers have attempted to develop various on-the-go or real time sensors and techniques to measure mechanical, physical and chemical soil properties as an alternative to tedious manual soil sampling and laboratory testing. As new on-the-go soil sensors are developed, different real-time and map-based variable rate soil treatments may become economically feasible. Sensors based on electric and electromagnetic measurement concept are being used widely these days [6].

For the small agricultural area, monitoring the soil pH changes is feasible. However, for the large scale areas, collecting the soil samples by traditional methods are very tedious and time consuming. Also, the soil pH measurement in laboratories is time consuming and requires sample preparation. Considering the need and scope of precision agriculture in India, this study was aimed to develop a real time soil pH measuring system which measures the geo-referenced soil pH directly in the field at specific locations. The soil pH measuring system with portable data logger was aimed to have the potential to eliminate many of the aforementioned constraints in soil pH determination in field. Data logging is a new technique which is helpful in real time logging of physical parameter i.e. geo referenced soil pH in the field conditions and mapping soil properties.

The present study has been planned with an objective to develop a tractor operated real time soil pH measuring system for mapping the spatial variation in soil pH.

MATERIAL AND METHODS

Selection of instruments/equipments. For the development of real time tractor operated soil pH measuring system a soil pH sensor, GPS receiver, a portable data logger and tractor mounted bund former were required. So, a contact type flat ended pH electrode (2124FE) and a global positioning system (6M GPS Module) were selected for measuring the soil pH directly in the field (Fig. 1). A portable data logger was fabricated which features latest technology support and helps in logging physical parameter with geo-referenced locations and save it into SD card. The portable data logger was synchronized with the soil pH sensor and GPS system and mounted on the tractor operated bund former. A data logger is an attractive alternative to either a recorder or data acquisition system in many applications. The data logger can handle inputs of up to 8 channel (4 analog/digital sensors each) and able to log data from interval of 600 sample/sec to 1 sample/week. A data logger is a self-contained unit that does not require a host to operate. It can be installed in almost any location and left to operate unattended. The data logger itself record, store and analyze the data (Fig. 2).

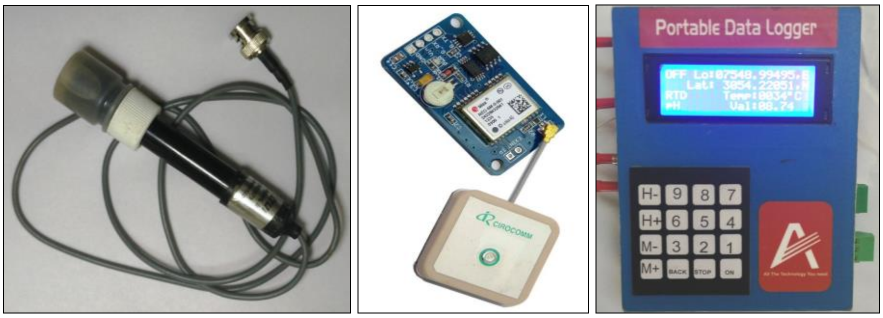


Figure 1. Soil pH sensor, GPS Reciever and Portable data logger

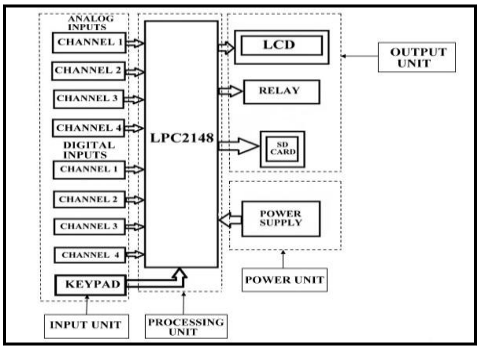


Figure 2. Operation of data logger system

Initially, various soil manipulating implements like cultivator, MB Plough, etc were tried for mounting the developed soil pH measuring system in the field. The proper mounting of the developed system on these implements was difficult and unfavorable for the safety of sensor due to high impact of soil force on pH sensor. Finally, a tractor operated bund former was selected for mounting the developed measuring system.

Development and fabrication of mechanism for integrating the soil pH measuring system on tractor operated bund former. The structural mechanism for mounting the soil pH measuring system on the tractor operated bund former was prepared in three dimensional solid modeling software tool called SoildWorks. The developed system consists of a platform made up of galvanized iron sheet, which was placed on the frame of the bund former. A wooden box made for placing the portable data logger and connecting wires was fixed on the frame of the bund former, keeping in view that there should not be any damage to the developed system (Fig. 3). A clamp for holding the pH electrode was also made by molding a galvanized iron sheet. A slot type arrangement was also made and welded on the one blade of bund former for attaching the clamp of sensor electrode. Initially, sensor probe was fitted vertically to the blade of bund former, but this arrangement was not suitable because when the implement was operated in the field, the soil transmitted a huge impact force to the body of sensor probe. This huge soil force could have easily damaged the delicate electrode of pH sensor. It was observed that mounting of the probe horizontally instead of vertically had received lesser impact. So keeping in view the probe was fitted horizontally on the blade of bund former.

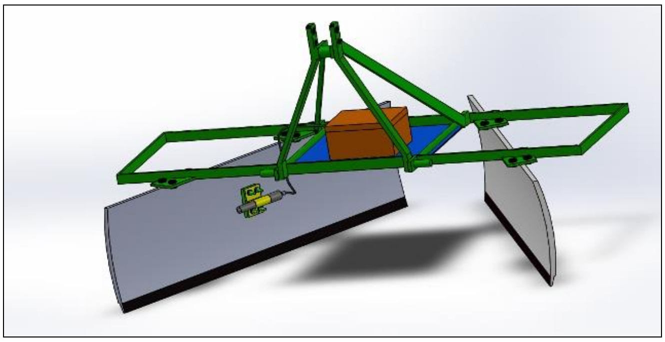


Figure 3. Structural mechanism for integrating the soil pH measuring system on tractor operated bund former

Calibration of soil pH sensor with data logger. The pH sensor should be calibrated before each measurement. So to calibrate for its optimum settings, the pH sensor integrated with data logger was calibrated in Soil Testing Laboratory, Department of Soil Sciences, PAU Ludhiana. The calibration was performed by selecting two standard buffer solutions of pH 7.00 and pH 4.01 or 9.18. The calibration of pH sensor was also done with reference soil samples collected from different locations and cities (Fig. 4) to get variation in the range of soil pH (Fig. 5). The collected soil samples had soil pH ranging from 5.95 to 8.35.

Figure 4. Soil samples collected from different locations and their pH measurement in laboratory

Figure 5. Calibration of pH sensor with data logger using collected soil samples

Experimental field location. The structural mechanism for integrating the soil pH measuring system was developed and fabricated at Research Hall, Department of Farm Machinery and Power Engineering, Ludhiana. The experimental field was located at 30°54'66.100" N latitude and 75°48'68.620" E longitude and the field experiment was conducted in 110 × 30 m (3300 m^2) area from February to May 2016 located at the Research Farm, Department of Farm Machinery & Power Engineering, Ludhiana, Punjab, India. The main plot was divided into 27 subplots of 30 × 4 m each which consists of three different tillage treatments i.e. conventional tillage (T1), no tillage (T2) and residue incorporated soil (T3) at three forward speeds (S1, S2 and S3) with three replications (R1, R2 and R3). The developed soil pH measuring system was operated in the field after every 10 day interval (Fig. 6). The soil sensor was properly calibrated before field experiment and the data was recorded, stored and analyzed.

ArcGIS 9.3 software was used for the mapping the spatial variation in soil pH determined by the developed soil pH measuring system and providing geographical information of soil pH. A GPS receiver and a portable data logger were used to record the geo referenced location of each soil sample or measurements. The recorded data was used to generate maps which showed spatial variation and information of the field. Maps of the soil pH were drawn and compared to access the precision of the developed soil pH measuring system.

Figure 6. Developed soil pH measuring system mounted on a tractor operated bund former

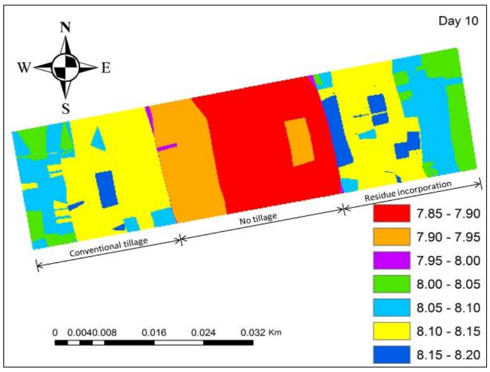
RESULTS AND DISCUSSION

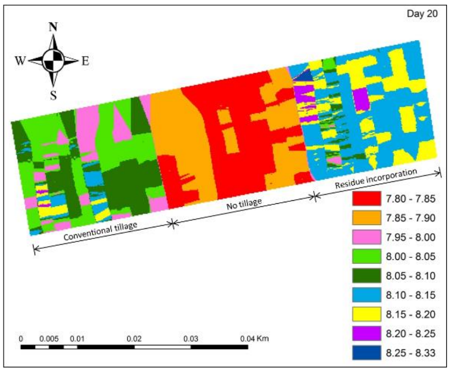
Spatial variation in soil pH measured by developed measuring system in the field from day 10 to 60. The developed measuring system was operated at research farm of Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana. The geo-referenced soil pH measured in field from day 10 to 60 was recorded by developed soil pH measuring system (Table 1). It was observed in conventional tillage (T1) that the soil pH measured with developed measuring system in the field varied from 8.10 to 8.15, 8.08 to 8.13, 7.98 to 8.12, 8.02 to 8.18, 8.03 to 8.14 and 8.01 to 8.13 for day 10, 20, 30, 40, 50 and 60 respectively. In no tillage (T2), the soil pH measured in the field varied from 7.83 to 7.94, 7.82 to 7.86, 7.84 to 7.89, 7.80 to 7.86, 7.61 to 7.74 and 7.60 to 7.75 for day 10, 20, 30, 40, 50 and 60 respectively. Similarly in residue incorporated soil (T3), the soil pH measured in the field varied from 8.08 to 8.15, 8.16 to 8.21, 8.08 to 8.12, 8.01 to 8.09, 8.12 to 8.18 and 8.05 to 8.17 for day 10, 20, 30, 40, 50 and 60 respectively. The field measurements showed that there was variation in soil pH over the field.

This study was undertaken to measure and map the spatial variability in geo-referenced soil pH in the field of 3300 m^2 using a real time soil pH measuring system. The mapping was done using ArcMAP 9.3 software for day 10, 20, 30, 40, 50 and 60 (Fig 7). The ArcMAP clearly showed that the field had variable soil pH and the developed real time tractor operated soil pH measuring system was capable to measure the spatial variation in soil pH in the field. The value of soil pH measured in the conventional tillage and residue incorporated soil was near to the actual pH of soil, while inaccurate in no tillage. The ArcMAP also shows that the spatial variation in soil pH was higher in conventional tillage and residue incorporated soil and least in no tillage. The lesser/inaccurate value of soil pH in no till condition was due to that the soil condition was untilled, unpulverized and presence of clods in the field causes inappropriate engagement of soil pH sensor with the topsoil. The maps generated by developed measuring system can be used for recommended application of lime, organic matter and fertilizers in the field. Researchers predicted that soil pH can be measured directly in the field and several high-resolution soil maps can be obtained for crop production of site-specific crop management on precision agriculture. The developed real time soil pH measuring system provided an efficient tool for predicting and mapping pH of soil within the field. High resolution soil pH field measurement maps generated on the basis of sensor measurements were able to depict the small spatial variability of the soil properties present within the field.

Table 1. Soil pH measured by developed measuring system in the field from day 10 to 60

Plot No	*Treatment*	*Average GPS coordinates in single run*		*Average soil pH*					
		Longitude (E)	*Latitude (N)*	*Day 10*	*Day 20*	*Day 30*	*Day 40*	*Day 50*	*Day 60*
1	T1S1R1	75^{O} 48’65.558”	30^{O} 54’65.044”	8.10	8.09	7.98	8.02	8.03	8.05
2	T1S1R2	75^{O} 48’65.697”	30^{O} 54’65.078”	8.10	8.12	8.01	8.05	8.06	8.01
3	T1S1R3	75^{O} 48’65.935”	30^{O} 54’65.302”	8.12	8.10	8.05	8.05	8.04	8.03
4	T1S2R1	75^{O} 48’66.219”	30^{O} 54’65.296”	8.14	8.10	8.08	8.15	8.13	8.02
5	T1S2R2	75^{O} 48’66.356”	30^{O} 54’65.435”	8.14	8.08	8.10	8.13	8.08	8.13
6	T1S2R3	75^{O} 48’66.601”	30^{O} 54’65.296”	8.15	8.13	8.12	8.16	8.07	8.10
7	T1S3R1	75^{O} 48’66.964”	30^{O} 54’65.411”	8.13	8.09	8.10	8.14	8.14	8.11
8	T1S3R2	75^{O} 48’67.262”	30^{O} 54’65.539”	8.14	8.09	8.09	8.17	8.08	8.08
9	T1S3R3	75^{O} 48’67.606”	30^{O} 54’65.576”	8.13	8.08	8.08	8.18	8.10	8.09
10	T2S1R1	75^{O} 48’67.933”	30^{O} 54’65.677”	7.94	7.85	7.85	7.82	7.73	7.74
11	T2S1R2	75^{O} 48’68.226”	30^{O} 54’65.635”	7.92	7.85	7.86	7.82	7.74	7.75
12	T2S1R3	75^{O} 48’68.477”	30^{O} 54’65.752”	7.93	7.86	7.86	7.83	7.73	7.73
13	T2S2R1	75^{O} 48’68.857”	30^{O} 54’65.900”	7.85	7.83	7.85	7.80	7.62	7.60
14	T2S2R2	75^{O} 48’69.019”	30^{O} 54’65.969”	7.83	7.84	7.84	7.81	7.61	7.60
15	T2S2R3	75^{O} 48’69.300”	30^{O} 54’66.078”	7.84	7.82	7.86	7.80	7.63	7.60
16	T2S3R1	75^{O} 48’69.570”	30^{O} 54’66.237”	7.88	7.84	7.88	7.84	7.62	7.61
17	T2S3R2	75^{O} 48’69.828”	30^{O} 54’66.241”	7.89	7.85	7.89	7.86	7.63	7.61
18	T2S3R3	75^{O} 48’70.119”	30^{O} 54’66.243”	7.87	7.85	7.86	7.86	7.61	7.63
19	T3S1R1	75^{O} 48’70.409”	30^{O} 54’66.530”	8.15	8.21	8.08	8.06	8.12	8.14
20	T3S1R2	75^{O} 48’70.749”	30^{O} 54’66.477”	8.14	8.16	8.12	8.06	8.15	8.17
21	T3S1R3	75^{O} 48’70.898”	30^{O} 54’66.581”	8.14	8.16	8.09	8.06	8.13	8.14
22	T3S2R1	75^{O} 48’71.160”	30^{O} 54’66.590”	8.15	8.17	8.09	8.09	8.18	8.10
23	T3S2R2	75^{O} 48’71.318”	30^{O} 54’66.666”	8.15	8.21	8.12	8.04	8.12	8.15
24	T3S2R3	75^{O} 48’71.644”	30^{O} 54’66.721”	8.12	8.18	8.12	8.07	8.13	8.16
25	T3S3R1	75^{O} 48’71.850”	30^{O} 54’66.800”	8.10	8.19	8.09	8.05	8.16	8.05
26	T3S3R2	75^{O} 48’72.068”	30^{O} 54’66.881”	8.10	8.20	8.11	8.02	8.15	8.12
27	T3S3R3	75^{O} 48’72.363”	30^{O} 54’66.755”	8.08	8.19	8.12	8.01	8.14	8.09





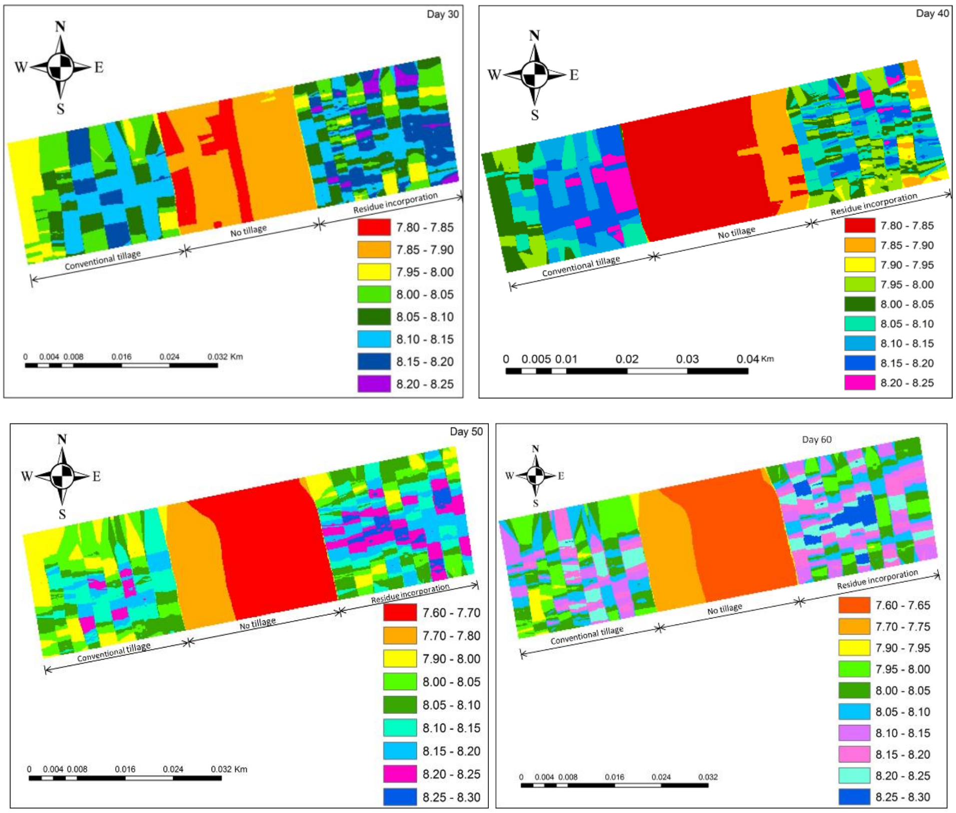


Figure 7. Spatial variation in soil pH measured by developed measuring system in the field for day 10, 20, 30, 40, 50 and 60

CONCLUSIONS

- Structural mechanism was developed for attaching the real time soil pH measuring system on a tractor operated bund former for measuring the real time geo-referenced soil pH directly in the field.
- The developed real time soil pH measuring system provided an efficient tool for predicting and mapping the pH of soil within the field.
- The geo-referenced soil pH measured in the field mapped by ArcMAP clearly showed that the field had spatial variation in soil pH and the developed measuring system was capable to measure the spatial variation of soil pH in the field.
- It was observed that in T1, the soil pH measured with developed measuring system in the field varied from 8.10 to 8.15, 8.08 to 8.13, 7.98 to 8.12, 8.02 to 8.18, 8.03 to 8.14 and 8.01 to 8.13 for day 10, 20, 30, 40, 50 and 60 respectively.

- In T2, the soil pH measured in the field varied from 7.83 to 7.94, 7.82 to 7.86, 7.84 to 7.89, 7.80 to 7.86, 7.61 to 7.74 and 7.60 to 7.75 for day 10, 20, 30, 40, 50 and 60 respectively.
- Similarly in T3, the soil pH measured in the field varied from 8.08 to 8.15, 8.16 to 8.21, 8.08 to 8.12, 8.01 to 8.09, 8.12 to 8.18 and 8.05 to 8.17 for day 10, 20, 30, 40, 50 and 60 respectively.

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RAZVOJ TRAKTORSKOG MERNOG SISTEMA ZA MAPIRANJE PROSTORNE PROMENLJIVOSTI pH ZEMLJIŠTA U REALNOM VREMENU

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Sažetak: pH zemljišta je važna karakteristika zemljišta koja igra važnu ulogu u utgoju biljaka. Zemljišni pH utiče na prinos useva, dostupnost nutrienata korenu biljaka i aktivnost mikroorganizama u zemljištu. Merenje prostornih promenljivosti pH vrednosti na manjim oblastima je izvodljivo. Ipak, za velike oblasti, određivanje pH većeg broja uzoraka zemljišta na uuobičajeni način u laboratoriji je naporno i dugotrajno. Imajući u vidu potrebe i opseg precizne poljoprivrede u Indiji razvijen je merni sistem za sakupljanje podataka u realnom vremenu, radi određivanja pH zemljišta direktno na parceli na pojedinačnim GPS lokacijama, integracijom pH senzora i GPS prijemnika sa prenosivim data logerom. Mapiranje zemljišta je vršeno radi praćenja prostorne promenljivosti pH zemljišta korišćenjem ArcGIS. Rezultati su pokazali promenljivost pH zemljišta i omogućili da se razvije merni sistem za merenje prostorne promenljivosti. Srednja pH vrednost izmerena ovim sistemom u različitim sistemima obrade zemljišta varirala je od 7.98 do 8.18, 7.60 do 7.94 i 8.01 do 8.21, redom.

Ključne reči: *merenje pH zemljišta, pH senzor, data loger, mapiranje, prostorna promenljivost*

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