DEVELOPMENT OF AN ON-THE-GO SOIL PH AND LIME REQUIREMENT SENSING SYSTEM

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BACKGROUND

Conventional soil sampling is both laborious and costly. This is especially true when farming in a site-specific manner because of the dense sampling required to produce a representative soil map. There are several projects worldwide currently focusing on the development of techniques to make sampling more time and cost efficient. There is a range of techniques that are currently being researched for this purpose, e.g. electromagnetic induction techniques (e.g. Triantafilis et al., 2000), electrical resistivity (e.g. Lund et al., 1998), diffuse spectral reflectance (e.g. Shibusawa, 2001), soil mechanical impedance (Alihamsyah & Humphries, 1991). These 'indirect' methods may be used to collect data sets that may be used to complement existing soil information for site-specific management. However, the use of the data is not straight forward and appropriate, often site-specific calibrations are required to infer the property of interest. Approaches to 'directly' measure soil chemical properties using ion-selective electrodes have been described by Adsett et al. (1991), Hummel & Birell (1995), Adamchuk et al (2003) and using Ion Sensitive Field-Effect Transistors (ISFETs) by Birrell & Hummel (1997), Viscarra Rossel & McBratney (1997) and Viscarra Rossel & Walter (2003). The possibility for a rapid determination of lime requirement was proposed by Viscarra Rossel & McBratney (1997, 2003). These studies form the basis for this work: the development of a robust, on-the-go soil pH and lime requirement sensing system.

OBJECTIVE

The purpose of this project is to develop a robust on-the-go soil pH and lime requirement sensing system. In this paper only experiences from the technological development are presented.

MATERIAL AND METHODS

The developed sensing system consists of the following; (i.) a soil sampling component, (ii) a soil analytical and sensing component, (iii) data collection and measurement algorithms.

Soil sampling

For the soil sampler to work properly, it is best to run the system continuously. The soil sampler is made up of a self-propelled waved spinning disc with a working depth of 20 cm, mounted on a single arm coulter from Yetter Farm Equipment (fig. 1). When the sampler is pulled along at speeds over 2 m/s, soil is thrown up behind the disc and is collected and transported through a tube by a material fan to a cyclone. The wind speed in the tube is about 30m/s, which theoretically is enough to transport soil particles with a diameter of $\leq$ 20mm. In reality this will only happen randomly since the wind speed just outside the inlet to the tube is much less. All particles transported through the tube will hit the centre of the fan wheel and thereafter be thrown out as dust into the cyclone. A small hydraulic motor powers the fan, and the fan speed is set to 3000 rpm.

Fig 1. When driving faster than 2 m/s the threaded disc throws up soil, which is collected with a material fan through a tube. The soil passes a cyclone and a rotating sieve before it is analysed in the analytical component.

The fan speed must not be too high as this will affect how long the soil particles stay in the cyclone. To prevent problems with straw and crop residues on the soil surface, two smaller discs (2965 Trash Master from Yetter Farm Equipment) are mounted in front of the spinning disc to clear away loose materials on the surface. This is necessary to avoid choking of the material fan. A “split ski” is also used to make sure that not to much straw is thrown up by the spinning disc. From the cyclone the soil falls into a rotating sieve, where the soil is sieved to a size fraction < 2 mm (fig. 2). The soil passing through the rotating sieve slides down to a measurement unit where approximately 2 cm^{-3} of soil is measured and passed into the soil analytical and sensing component.

Fig 2. The rotating sieve (seen from above) consists of a cylindrical shaped sieve and a small motor (60 rpm). Larger particles and straw passes through the rotating sieve.

Soil analytical and sensing component

In the soil analytical and sensing component the sieved soil is mixed with a chemical solution (0.01M $CaCl_2$ or a lime requirement buffer) and the soil chemical reaction is measured to quantify changes in soil pH. This is done in the following way. Soil is transferred into the analytical component using a small compressed air cylinder. The soil falls into the mixing chamber adapted from a coffee machine (Wittenborg, FB7600) (fig. 3). To improve its function in our application, we added a pinch valve controlling the waste outlet. In the mixing chamber the soil is mixed with the chemical solution, which is pumped into the system using a peristaltic pump (Watson Marlow 400F/R1) at approximately 6 ml/second. The system is cleaned using a windshield washer pump with a capacity of 25 ml/s. Within the mixing chamber there is a flat spinning disc ensuring proper mixing of the chemical and the soil. In the centre of the mixing chamber an on-line ISFET-sensor (SentrON-LINE) is installed to measure the chemical reaction and quantify pH. Data from the sensor is logged at 10 Hz.

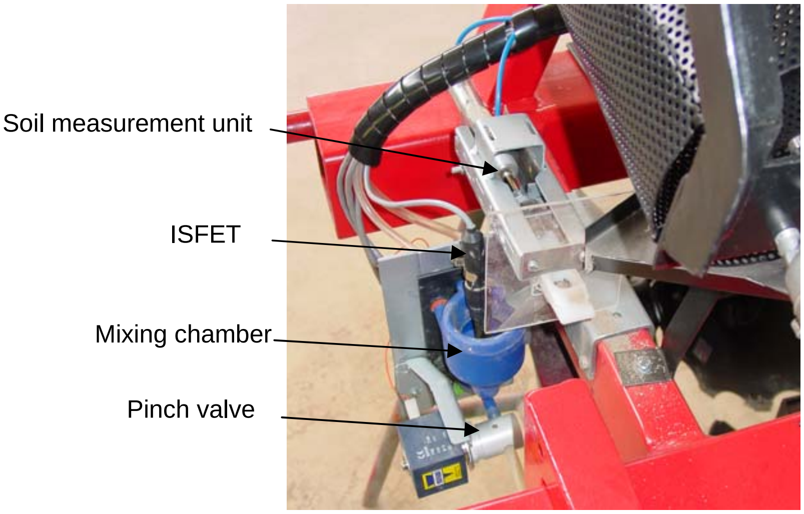

Fig 3. The soil sample is analysed in a mixing chamber. Below the mixing unit a pinch valve is located to control the outlet from the mixing chamber. The ISFET sensor is located in the centre of the mixing chamber. Above the mixing chamber the soil measurement unit is located. When driving in the field, the unit is covered with a lid.

Data collection and measurement algorithms

The system that controls the sensing and analytical component also logs data from the ISFET and the geo-position of the collected soil sample. The system is based on a PC and a FieldPoint FP 1000 (National Instruments). The sensor data is measured with an analog input unit (FP-AI-100) while motors, valves and pumps are controlled with a relay unit (FP-RLY-420). Some additional electronics are needed to regulate voltage to the ISFET sensor and a unit to control the compressed air cylinder. The software that controls the system is written in Labview (National Instruments).

RESULTS

The results presented are preliminary since this is an ongoing project.

Soil sampling

The soil sampler functions properly at speeds above 2 m/s. In our trials the running speed has been about 2.5 m/s. The volume of soil collected and sieved is sufficient and the soil measurement unit is filled within a second. Initially, straw and crop residues on the soil surface choked the fan. We solved this by mounting the “Trashmaster” in front of the waved spinning disc. The second problem occurred when using the system on heavy clay soils in “muddy” conditions. In this instance the spinning disc did not sample any soil and the system did not function although the fan, cyclone and the rotating sieve did.

The system only measures the volume of soil and not its mass, thus the repeatability of soil measurement will be affected. Similarly for chemical solution measurements using the peristaltic pump. The precision of soil volume measurements and solution measurements using the peristaltic pump are shown in table 1.

	Soil (g)	Chemical solution (ml)
Number of readings	30	30
Average value	1.925	11.31
Max value	2	11.43
Min value	1.86	11.14
Std dev.	0.037	0.08

Table 1. Results when testing the repeatability of the soil and chemical volume measurement.

The spinning disc soil sampler leaves only a small track, with minimal soil and crop disturbance (fig. 4). However, the intention is not to drive the sensor in fields during the growing season.

Fig 4. The spinning disc leaves a groove about 20 mm wide. Soil particles not collected by the material fan are also seen beside the groove.

Soil analytical and sensing component

An example of an output signal from the sensor can be seen in figure 5. Note that the chemical reaction (the slope of the curve) is different between the two samples. For more details see Viscarra Rossel et al. (2004). The main problem with the analytical system is the risk of soil clogging the online ISFET sensor installed in the centre of the mixing chamber. However, when this becomes a problem the ISFET sensor may be installed to one side of the mixing chamber.

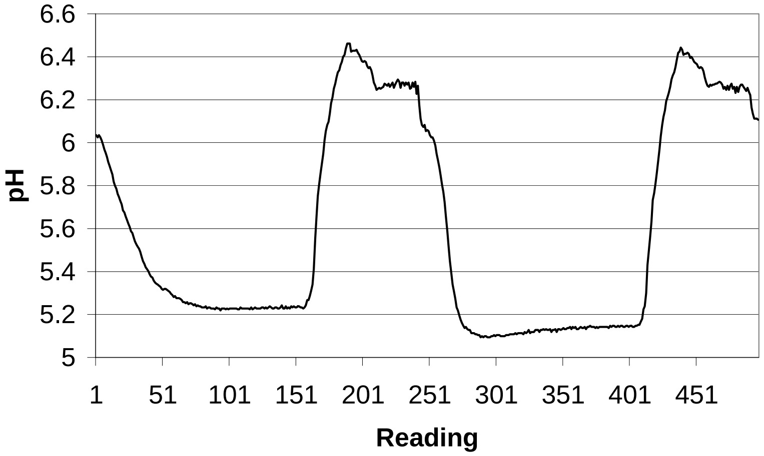

Fig 5. An example of the signal from the sensor can be seen above. The measurement starts when the soil enters the mixing chamber and the pH value decreases. The measurement ends when cleaning water enters the system and the pH-value increases to pH 6.4. During the cleaning cycle water and chemicals cleans the mixing chamber before chemical and the next soil sample enters the mixing chamber.

Preliminary field studies shows promising results. When driving in the field (fig. 6) we collect about 8 samples / hectare when driving on 24 metres tramlines. The capacity of the system is about 20 hectares / hour (24 metres tramlines). Preliminary field results are reported in Viscarra Rossel et al. (2004).

Fig 6. The on-the-go soil sensing system does not operate properly in soils that are wet and have high clay content, i.e. ‘sticky muddy’ soil

An example of a post plot map collected with the on-the-go soil sensor can be seen in figure 7.

ACKNOWLEDGEMENT

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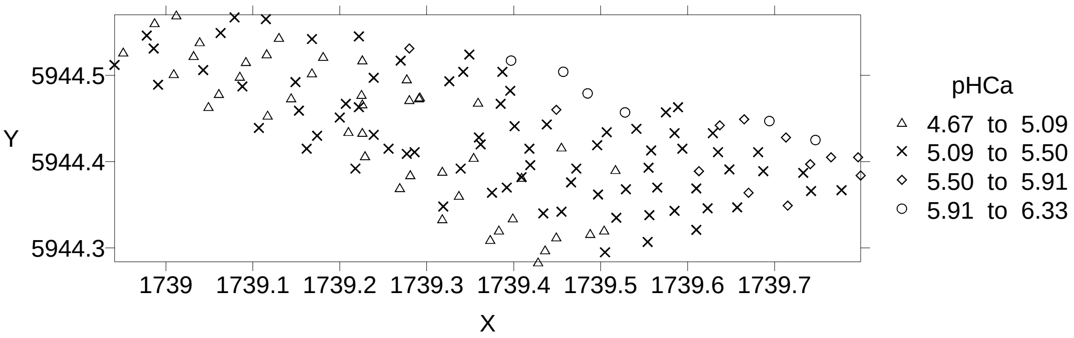

Fig 7. Example of a post plot map collected with the on-the-go soil sensor.

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