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Development of On-the-go Soil Sensor for Rice Transplanter*

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Abstract

The objective of this paper was to provide the development of on-the-go soil sensor for rice transplanter, particularly from a perspective of precision agriculture applications. Ultrasonic sensor, electrodes and platinum resistance thermometer were employed for topsoil depth (*TD*) and apparent electrical conductivity (EC_a) measurement. Soil fertility value (*SFV*) defined as new soil parameter, which consisted of EC_a / *TD*. The results of field test revealed that the developed equipments could measure the *TD* (R^2 = 0.999), and the *SFV* had a strong relationship with measured EC (R^2 = 0.937).

[Keywords] on-the-go soil sensor, topsoil depth, apparent electrical conductivity, soil fertility value, precision agriculture, ultrasonic sensor, electrode

I Introduction

The adoption of precision agriculture techniques for fertilizer management has the potential for improving agronomic, economic and environmental efficiency in the use of such input. While implementing best management practices around the world, it was observed that the most efficient quantities of agricultural inputs vary across the topography due to various naturally occurring, as well as man-induced, differences in key productivity factors such as water and nutrient supply. Identifying and understanding these differences allow for varying crop management practices according to locally defined needs. Spatially-variable management practice and usage of sensor fusion concept have become the important role of precision agriculture (Malekia, 2008). Description of field variability is also a key concept of precision agriculture (Robert, 1993). Variations in crop vegetation growth typically respond to differences in these microenvironments together with the effects of management practice. Traditionally differences in physical, chemical and biological soil attributes have been detected through soil sampling and laboratory analysis (Shibusawa, 2006). The cost of sampling and analysis are inefficient and difficult to obtain enough number of samples to accurately characterize the landscape variability. This economic consideration resulting in low sampling density has been recognized as a major limiting factor (Mouazen, 2005; Shibusawa, 2001). Soil electrical conductivity, which is known as EC, is the ability of soil to conduct electrical current. The EC is well known by producer to evaluate not only the soil salinity but also the soil fertility. Agricultural application of apparent soil electrical conductivity (EC_a) has evolved into a widely accepted means of establishing the spatial variability of several soil physico-chemical properties that influence the EC_a measurement (Corwin, 2004). Recent developments in EC sensors and their ability to produce EC variation maps has attracted much attention among farmer about potential applications of this sensor for improving field management (Sudduth, 2001). Especially, bulk soil electrical conductivity (EC_{bulk}) is one sensor-based measurement that can provide an indirect indicator of important soil properties. As for soil sensor for paddy field, however, there has been little research investigation. Especially, there is no report available in terms of soil sensor for paddy flood condition. Furthermore, there are only a few days available for investigating before rice transplanting, in order to observe the field spatial variability, the alternative sensing method was needed instead of conventional soil sampling and analysis.

The objective of this research was to design and implement on-the-go soil sensing system for measuring topsoil depth and apparent soil electrical conductivity for rice transplanter in order to achieve relative evaluation.

II Materials and Methods

1. Topsoil depth measurement system

The prototype was applied 6 rows type rice transplanter (PZ-60, Iseki) In this paper the authors described ultrasonic

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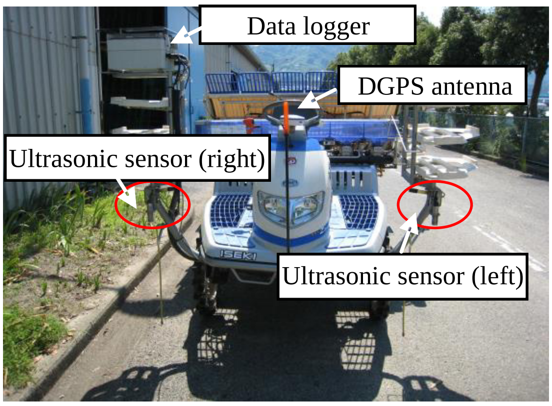
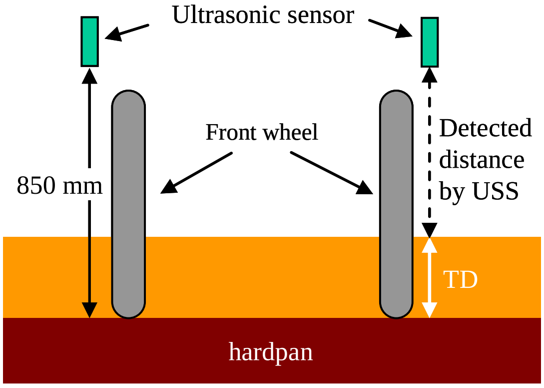
distance sensor (USS) that performs contactless measurement of the topsoil depth in the paddy field. The system consisted of a couple of USS (E4PA- LS200-M1-N, Omron) that were set in front of the rice transplanter at 850 mm height was shown in Fig. 1 (a). According to the specification, the USS is affected by ambient temperature (i.e. ± 1 % F.S. (full scale: 2 m) in the temperature range of -10 to 55 °C). This specification could be acceptable for the distance measurement in this study. The *TD* was defined as the stable height (i.e. 850 mm) minas detected distance by USS was shown in Fig. 1 (b). In this study, we applied average of detected distance for The *TD* estimation was given by Eq. 1.



(a)



(b)

Fig. 1 Prototype topsoil depth measurement system (a) photo of ultrasonic sensor (b) schematic diagram of topsoil depth sensing

$$TD = 850 - \frac{(D_{left} + D_{right})}{2} \qquad (1)$$

where D_{left} is a distance from left sensor to ground and D_{right} is a distance from right sensor to ground.

According to the specifications, the prototype USS could be measured with 5 Hz interval. This study applied the *TD* value based on a moving average of 5 dataset each. If the ground surface is flood condition, the USS might measure the distance from sensor to water surface. However, we assumed that the influence of *TD* variability due to surface water is smaller than that of hardpan condition in a relative field evaluation. Because farmers normally maintain flat surface condition by puddling before transplanting, therefore we decided to apply the USS method for relative *TD* measurement and evaluation.

2. Soil electrical conductivity sensor

The soil electrical conductivity sensor (ECS) was developed for measuring EC_{bulk} during the rice transplanting in real time. The ECS consisted of a couple of wheel type electrodes made of stainless, which mounted on the front wheels was shown in Fig. 2. The diameter and width of the ECS were 53 cm and 5 cm, respectively. The ECS goes into the soil and maintains a spacing of 1.5 m between two electrode sensors located one end of the front wheels of rice transplanter with alternate current of 1 kHz frequency flows between electrodes was shown in Fig. 3.

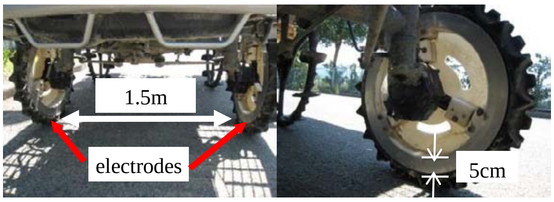


Fig. 2 Prototype soil electrical conductivity sensor

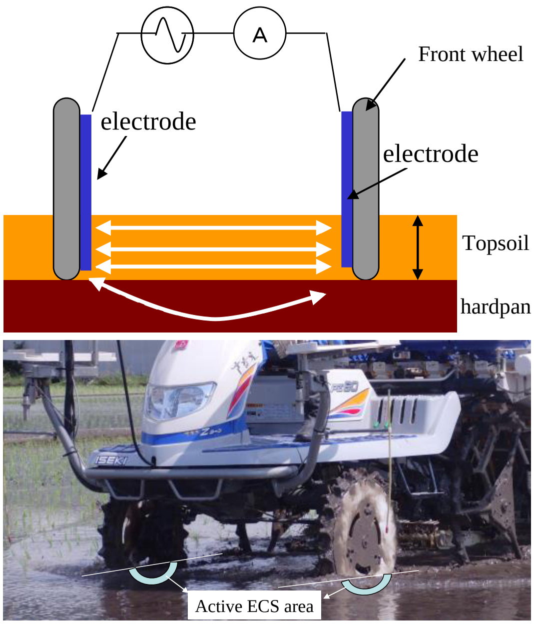


Fig. 3 Schematic diagram (upper) and photograph (bottom) of the electrical conductivity sensor

Theoretically, EC_{bulk} measurement is influenced by soil conditions, including depth of soil and moisture content, temperature (Sudduth *et al*., 2001; Ruijun *et al*., 2011). This