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Basic Study on the soil water distribution measurement using stick type sound source and sensors
縦挿型音源およびセンサを用いた土壌水分分布計測に関する基礎検討

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1. Introduction

In late years, a problem of the global water shortages especially in developing countries becomes clear, and is told that efficiency of the agriculture water is necessary[1]. To that end, grasp of water distribution as one of the parameters to affect plant upbringing in the soil is particularly necessary. However, the existing soil water evaluation method is the point measurement using the soil moisture sensor. Therefore, the practical use is difficult because a large number of sensors are necessary to measure a wide range around the plant root zone.

On the other hand, the sound wave propagation has a possibility that the water distribution around the plant root zone can be estimated with a small number of sensors. We confirmed that both horizontal and vertical propagation velocity distribution is related to the water distribution using SLDV (Scanning Laser Doppler Vibrometer) experimentally[2-3]. Though the measurement using the laser is not realistic, by inserting a stick type sound source and sensors perpendicularly for the soil, the growth situation of the plant in the rooting zone has a possibility to grasp from the distribution of the propagation velocity.

Therefore, in this study, we proposed a soil water distribution measurement using sound wave vibration. This time, using stick type sound source and sensors, sound wave propagation measurement in shallow underground and a propagation velocity of sound when water distribution existed are studied.

2. Principle of proposed method

Figure 1 shows the conception diagram of our proposed method. Using the negative pressure difference irrigation system, water distribution in the soil is formed in plant rooting zone. From the distribution of the propagation velocity of sound, water distribution is estimated around the rooting zone. Utilizing the water distribution information, the irrigation system is controlled to supply only the water which a plant needs.

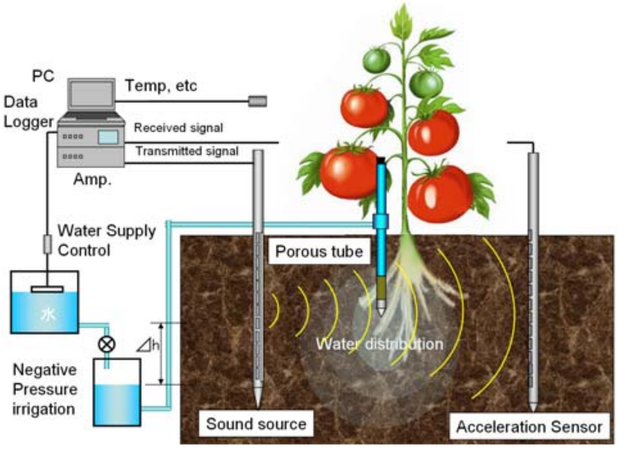

Fig. 1. Fundamental concept of our proposed method.

3. Stick type sound source and sensors

Fig.2(a) shows the profile of the stick type transmitter ($326 \times 30 \times 30\text{mm}^3$). There are five circular holes in the housing (conifer materials), and has small giant magnetostriction vibrator (OPT Co., Ltd, GPECKER) built-in. Fig.2(b) shows the profile of the stick type receiver ($300\times30\times15\text{mm}^3$). There are five circular holes in the housing (broad leaf tree), and has acceleration sensor (Ono Sokki Co., Ltd., NP-3110) built-in. Each vibrator's and sensor's top are glued together with a PP (polypropylene) sheet affixed to the wood surface. The main body of giant magnetostriction vibrators and sensors are not adhered to the housing.

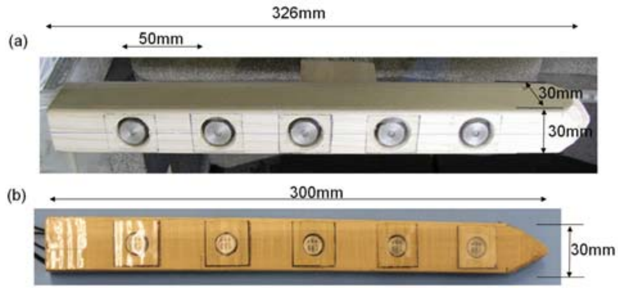

Fig. 2. Stick type sound source & sensors.
(a) Transmitter, (b) Receiver.

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4. Basic experiment for propagation velocity measurement in sand

Using a transmitter and a receiver, propagation measurement in sand was performed. Figure 3 shows the experimental setup using a sand tank (500×400×300mm^3). Shore sand of particle size about 200-300um is used for the soil. The distance between a sound source and a sensor is 35cm, the pressurization of the sand using a weight of 25 kg for around three days.

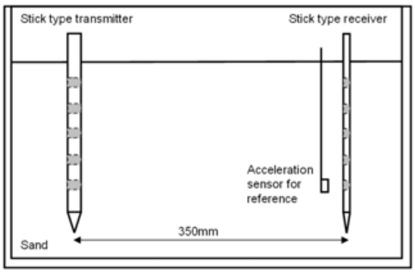

Fig. 3. Basic setup for vibration propagation measurement.

Figure 4 shows the examples of the received waves using sine burst wave (2kHz, 5cycle). From this figure, propagation velocity can be measured by the distance of 350mm. In addition, the estimated speed of sound of this experiment was approximately 160m/s.

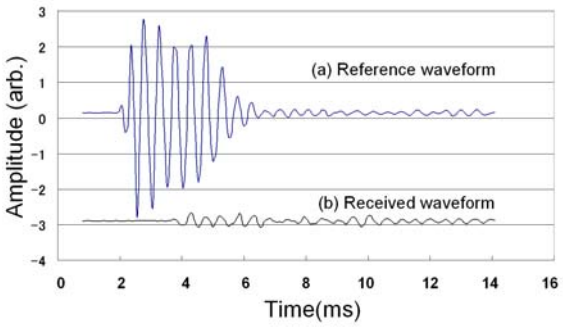

Fig. 4. Examples of waveform. (a)Reference waveform , (b)Received waveform.

5. Change of the propagation velocity by the water distribution

By drip irrigation in the sand tank inside, water distribution change with time is generated, and measured the change of propagation velocity and volume water content for the comparison with the stick type sensor and soil moisture sensor. Figure 5 shows the experimental setup. To form water distribution in the soil, two pieces of polypropylene sheets which opened a circular window are sandwiched a liquid transportation cloth and supplied it with water using a syringe from the upper part. The distance between a transmitter and a receiver is 320mm and drip irrigation by liquid transportation cloth is performed in the central part of a sand tank. The position of a circular window is 5cm depth from the sand surface, and the sound source and the acceleration sensor that used for a measurement is about 10cm depth from the sand surface. The water supply is performed every three minutes. Soil moisture sensors are buried in the vicinity around the circular window. Measurement result is shown in Fig.6. From this figure, volume water content by a soil moisture sensor is according to water supply. At the same time, we can confirm that propagation velocity is roughly proportional to the volume water content.

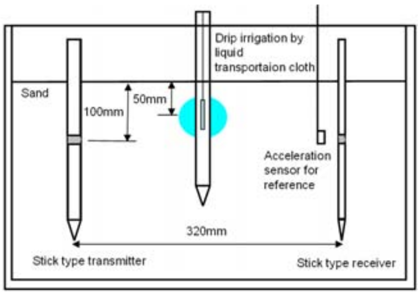

Fig. 5. Experimental setup for water distribution estimation.

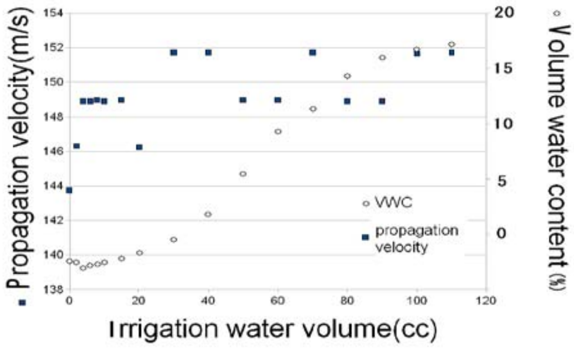

Fig. 6. Irrigation water volume vs. propagation velocity and volume water content. White circle; Volume water content by soil moisture sensor, Black square; Calculated propagation velocity.

6. Conclusion

By using stick type sound source and sensors, we can confirm that the possibility of the water distribution measurement using sound wave. In the future, we will improve the estimation of propagation velocity and we intend to examine whether our method can apply even in the case that a plant is growing up in soil for gardening.

Acknowledgment

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References

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