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# Evaluation of soil pore-water salinity using a Decagon GS3 sensor in saline-alkali reclaimed tidal lands

S.J. Lim [a,1], M.N. Shin [b,1], J.K. Son [c], J.D. Song [c], K.H. Cho [d], S.H. Lee [e], J.H. Ryu [e], J.Y. Cho [f,*]

[a] National Academy of Agricultural Science, RDA, Wanju-gun, Republic of Korea
[b] Department of Food Science & Technology, Chonbuk National University, Jeonju, Republic of Korea
[c] Department of Rural Construction Engineering, Chonbuk National University, Jeonju, Republic of Korea
[d] Division of Computer Science & Engineering, Chonbuk National University, Jeonju, Republic of Korea
[e] National Institute of Crop Science, RDA, Wanju-gun, Republic of Korea
[f] Department of Bioenvironmental Chemistry, Chonbuk National University, Jeonju, Republic of Korea

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ABSTRACT

This study develops general equations to extend the applications of a GS3 salinity sensor to a wide range of soils including critical saline-alkali reclaimed tidal lands. The GS3 sensor measures volumetric water content, temperature, and electrical conductivity independently. As a result of laboratory-based sensor calibration testing, it was determined that the electrical conductivity of soil pore-water solution ($EC_p$) with slight to moderate salinity can be computed from the bulk EC ($EC_b$) without calibration. The $EC_b$ data obtained from the sensors were reconstructed via the calibration equation. We compared these results to $EC_p$ observed from suction cup samples. A good correlation was observed between the calibrated $EC_p$ and the observed $EC_p$, in low-to high-salinity soils. However, the calibrated $EC_p$ at very high salinity underestimates the observed $EC_p$. Based on these results, we conclude that these sensors offer clear additional value in ensuring control of the root-zone salinity, and in compensating for weather influences.


## 1. Introduction

The West coast of South Korea meets the sea gradually and the inter-tidal belt is comprised of mud-flats that offer many opportunities for the implementation of reclamation projects in order to solve food shortage and arable land expansion. The total area earmarked for reclamation in South Korea amounts to 157,000 ha, with 76,000 ha already developed and 60,000 ha under or awaiting development (Cho et al., 2003). A representative example relating to the coastal reclamation projects in South Korea is Saemangeum Development Project. It will create 283 $km^2$ of reclaimed land and a lake as large as 118 $km^2$ by constructing the world's longest 33.9 km sea dike connecting Gunsan and Buan on the west coast of South Korea. One-third (89.7 $km^2$) of the total area to be developed will be utilized for the agricultural sector (Son et al., 2016). Specially, coastal farmlands including reclaimed tidal lands with high levels of soluble salts and exchangeable $Na^+$ can adversely affect plant growth and crop yield (Bernstein, 1975). Therefore, in order to control and evaluate the hazard of soil salinity, more accurate measurement of soil salinity is critical.

Soil salinity measurements are complicated, because measurement errors can be caused by factors including temperature, organic matter, moisture, and soil texture. The development of new measurement methods and equipment capable of evaluating soil salinity status remains an active field of research (Rhoades et al., 1976, 1989; Hilhorst, 2000). The ideal measurement tool for soil salinity status should read the majority of influencing components simultaneously and in the same location as quickly as possible to register the current values of interest (Wilczek et al., 2012).

Many techniques exist to measure soil salinity. The standard method requires measuring the electrical conductivity of aqueous extracts of saturated soil-pastes or of other soil-to-water ratio extracts. However, these methods are time-consuming and usually not representative of the salinity of soils in field conditions. In recent years, multiple sensors have been developed to assess soil salinity with continuous and non-destructive measurements. Capacitance and resistivity sensors can be used to continuously monitor the electrical conductivity of soil pore-water solutions in a non-destructive way; however, dielectric readings of capacitance sensors operating at low frequencies are normally biased by high soil electrical conductivity (Scudiero et al., 2012). It is generally accepted that soil electrical conductivity sensors are affected by soil moisture content (Evett et al., 2009; Kinzli et al., 2012). Despite the availability of the FDR salinity sensor (Wilczek et al., 2012),

* Corresponding author.
*E-mail address:* soilcosmos@jbnu.ac.kr (J.Y. Cho).
[1] S.J. Lim and M.N. Shin contributed equally to this work.

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ECH2O salinity probe (Scudiero et al., 2012), WET salinity sensor (Kumar et al., 2008), and 5TE sensor (Decagon Devices, 2012), salinity sensors are rarely used to make real-time soil salinity measurements for continuous data logging. Some reasons for the limited use of these sensors are the requirement of soil-specific calibrations, salinity sensitivity, and poor sensor reliability. To estimate the application range of salinity sensors for reclaimed tidal lands with highly salinity, the devices should be calibrated and validated under field conditions. The aim of this study is to develop general equations to extend the GS3 salinity sensor's application to a wide range of soils, including critical saline-sodic reclaimed tidal lands.

## 2. Materials and methods

### 2.1. Experimental fields

This study was carried out from May 2014 to October 2015 in inner reclaimed tidal lands located in Gyehwa-myeon, Buan-gun, Jeollabuk-do, South Korea (35°79′45″N, 126°63′77″E) (Fig. 1). The soils have thin, dark gray silt loam Ap horizons, and were formed in recently-reclaimed fluvio-marine plain alluvium with a high salt content (NIAST, 2000). The reclaimed tidal lands are composed of saline-sodic soils, and are characterized by a high pH, soluble Na carbonates and bicarbonates, and electrical conductivity. The dominant soil texture is silt and silt loam. The fundamental soil properties are listed in Table 1. At the Buan-gun weather station, the average annual temperature is 12.5 °C, average annual precipitation ranges from 1150 to 1200 mm, and 50–60% of the precipitation falls during the rainy season (Son et al., 2016).

### 2.2. Soil analysis

The soil properties determined were: pH, soil texture, total organic carbon, cation exchange capacity (CEC), and electrical conductivity (EC). Soil samples were air-dried and sieved to <2 mm. pH was potentiometrically measured in distilled water and in 1 M KCl at a soil dry weight-to-solution ratio of 1:2.5. Soil texture was classified via the pipette method and CEC was measured using the ammonium acetate method. Total organic carbon was deter-


**Fig. 1.** Location of the experimental fields.