Research article

Temporal and Spatial Distributions of Soil Apparent Electrical Conductivity in Paddy Rice Fields, Khon Kaen, Thailand

KATSUYUKI SHIMIZU*
Tottori University, Tottori, Japan
Email: shimizu@tottori-u.ac.jp

NAHO NOHARA
Hokkaido University, Hokkaido, Japan

TADAO YAMAMOTO
Hokkaido University, Hokkaido, Japan

TAKASHI KUME
Ehime University, Ehime, Japan

CHULEEMAS BOONTHAI IWAI
Khon Kaen University, Khon Kaen, Thailand

Received 15 January 2019 Accepted 5 May 2020 (*Corresponding Author)

Abstract The temporal and spatial distribution of soil apparent electrical conductivity (ECa) was measured to elucidate the process of soil salinization in rainfed paddy rice fields in Khon Kaen, Thailand. Soil ECa was measured in 2.3 ha of paddy fields using a ground conductivity meter, utilizing the principle of electromagnetic induction. The average soil ECa was measured at 150 cm and 75 cm depth at 10 m intervals. Observations were conducted every two weeks for two months, from mid-May 2018 to mid-July 2018. The collected data were interpolated using an inverse distance weighted method with 1 m intervals and then analyzed in terms of temporal and spatial distributions. The results showed that (1) higher soil ECa was observed in the northern part of the study area near a swamp throughout the monitoring period; (2) the average soil ECa at a depth of 0–75 cm ranged from 233 to 282 mS/m, while it ranged from 236 to 268 mS/m at a depth of 0–150 cm; (3) the average soil ECa in the upper layer was slightly higher than that of the lower layer in May, but this difference became smaller over time and the situation reversed in mid-July; and (4) a larger spatial distribution was observed in the upper layer compared with the lower layer based on the difference of a coefficient of variation of soil ECa. A soil salinization process was clearly observed.

Keywords electric conductivity, soil salinization, rainfed paddy fields, wet season, resilience

INTRODUCTION

In Thailand, saline soil covers an area of about 2.3 million ha, especially in inland areas (Pongwichian et al., 2013), and the accumulation of salt occurs in rainfed paddy fields. A major source of the salt is the Rock Salt Member of the Maha Sarakham Formation, which consists mainly of rock salts, wherever it is exposed or lies close to the surface. However, other potential sources of salt were formerly classified as salt-free strata (Wongsomsak, 1986). The management of these soils is very problematic and strictly depends upon the degree of salinization and the mode of the salt-forming processes. As general countermeasures, the management of these soils involves leaching, proper drainage control, land leveling, surface mulching, organic amendments, deep plowing, and the use of salt-tolerant plant varieties (Land Development Department). However, before taking any countermeasures, it is important to understand to what extent fields are affected by salt. Topark-Ngarm et al. (1990) conducted physical and chemical analyses of soil samples collected from a depth of 30 cm at 5 cm intervals in Ban Thum, Khon Kaen. Hanchai et al. (2010) monitored changes in biotic activity in relation to the chemical and physical properties of salt-affected soil before and after tree planting. However, the high-resolution temporal and spatial distributions of salt accumulation have not been well studied in the Khon Kaen Province.

OBJECTIVE

This study aimed to elucidate the high-resolution temporal and spatial distribution of soil apparent electrical conductivity (ECa) in paddy fields and areas adjacent to them in Khon Kaen, Thailand. When combined with groundwater level fluctuation, rainfall, and microtopography data, the monitoring results should contribute to the understanding of the soil salinization mechanism.

METHODOLOGY

Measurement and analysis of soil ECa

Although there are many saline-damaged farmlands in northeastern Thailand, a rain-fed paddy rice block of Ban Pasan village in Khon Kaen was selected as a study site because of its clear spatial distribution of the degree of salinity. The study area, in Ban Pasan, Khon Kaen, encompassed paddy fields and an adjacent forest and swamp (N16.296° W102.612°; elevation 243 m). The difference in elevation between the south and north ends of the monitoring area is 28 cm and the area is quite flat (< 1/1,000). The groundwater level in the study area ranged from 140 cm below the ground surface in April to 0 cm in September. Soil ECa was measured using a ground conductivity meter (EM38-MK2; Geonics Limited), which simultaneously measured both quad-phase (conductivity) and in-phase (magnetic susceptibility) components within two distinct depth ranges, without any requirement for soil-to-instrument contact (GEONICS). With a maximum effective exploration depth of 150 cm, this meter is used for agricultural, archaeological, and general soil science purposes e.g. Kume et al. (2003), Zukemura et al. (2016), and Rafael et al. (2011).

Area of soil EC

Fig. 1 Study area

The study area is shown in Fig. 1. The yellow dotted line indicates the domain of the ECa survey. Rice had been planted in a rainfed paddy in the southern part of the domain, with a fallow area in the center. A swamp was located to the northeast, and a tree plantation was located to the west. Soil ECa measurements were conducted at – 10 m horizontal intervals, with about 150–160 points, at two different depths, 75 cm and 150 cm vertically. Measurements were collected five times between 16

May 2018 and 11 July 2018, every two weeks. The collected soil ECa data were interpolated using an inverse distance weighted method with a 1 m mesh.

RESULTS AND DISCUSSION

Temporal Distribution of Soil ECa

The average soil ECa in the upper soil layer (0–75 cm) and the deeper layer (0–150 cm) are summarized in Tables 1 and 2, respectively. The average soil ECa between 0 and 75 cm ranged from 233–282 mS/m, while it ranged from 236–268 mS/m between 0 and 150 cm. The average soil ECa in the upper layer was slightly higher than that of the lower layer in May, but this difference reduced over time, with the situation being reversed in mid-July. The average ECa peaked in late May, with an average ECa of 282.3 mS/m at 0–75 cm and 268.0 mS/m at 0–150 cm. The highest median ECa and the highest coefficient of variation (CV) occurred in late May at both depths.

Table 1 Summary of soil ECa in the shallow layer (0–75 cm)

mS/m

Date	Average	Max	Min	Median	STD	CV
2018/5/16	247.8	928.6	32.6	214.5	141.9	0.57
2018/5/30	282.3	989.1	35.2	217.2	198.0	0.70
2018/6/14	243.0	982.9	26.1	203.8	149.7	0.62
2018/6/27	242.0	971.4	24.1	217.4	150.5	0.62
2018/7/11	233.1	895.9	27.2	214.5	133.0	0.57

Table 2 Summary of soil ECa in the deeper layer (0–150 cm)

mS/m

Date	Average	Max	Min	Median	STD	CV
2018/5/16	243.3	769.7	52.7	214.0	103.3	0.42
2018/5/30	268.0	987.3	39.2	225.2	155.7	0.58
2018/6/14	236.1	928.4	35.1	211.0	120.8	0.51
2018/6/27	241.2	773.0	38.2	223.4	120.2	0.50
2018/7/11	237.6	802.2	41.2	216.5	112.2	0.47

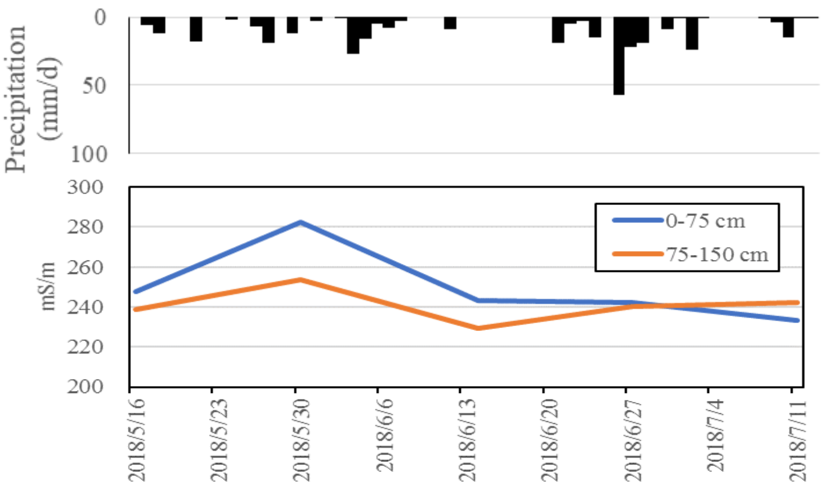

Fig. 2 Average soil apparent electrical conductivity (ECa) in the upper (0–75 cm) and lowest layers (75–150 cm) and daily rainfall

The average soil ECa in the lowest layer (75–150 cm) was then calculated, as shown in Fig. 2. The difference between the ECa in the upper soil layer (0–75 cm) and the lowest soil layer (75–150 cm) was greatest during May, but the difference reduced, and the ECa of the lowest layer was higher than that of the upper layer from late June. It is generally understood that saline water moves upwards by capillary action, and the increasing difference in ECa in the upper and lowest soil layers can be explained by capillary action. The reversal of the difference between the upper and the lowest layers might have been due to rainfall during late June and there was actually about 100 mm of rainfall (at the Khon Kaen airpoirt which is the nearest whether station from the study site) during the three days from June 25-27, 2018.

Spatial Distribution of Soil ECa

Figure 3 shows the spatial distribution of soil ECa at different depths. Higher soil ECa at both depths was observed in the northern part of the study area near the swamp throughout the monitoring period. There were some spot high ECa values in the southern paddy fields in May; however, these were lower in June and July. At a glance, the ECa values were highest during May, then decreased in June and July. The ECa in and around the rainfed paddy field was about 200 mS/m. The FAO states that rice is a salt-sensitive crop, with an ECa threshold of 300 mS/m (FAO, 2002). As shown in Figure 3, the ECa in the central and northern areas exceeded this threshold; therefore, these areas were left fallow due to the high salinity. The reason of high salinity of the central and northern part of the study area is to be discussed by considering spatial and temporal distribution of groundwater level fluctuation, soil type, and inundation of ground surface.

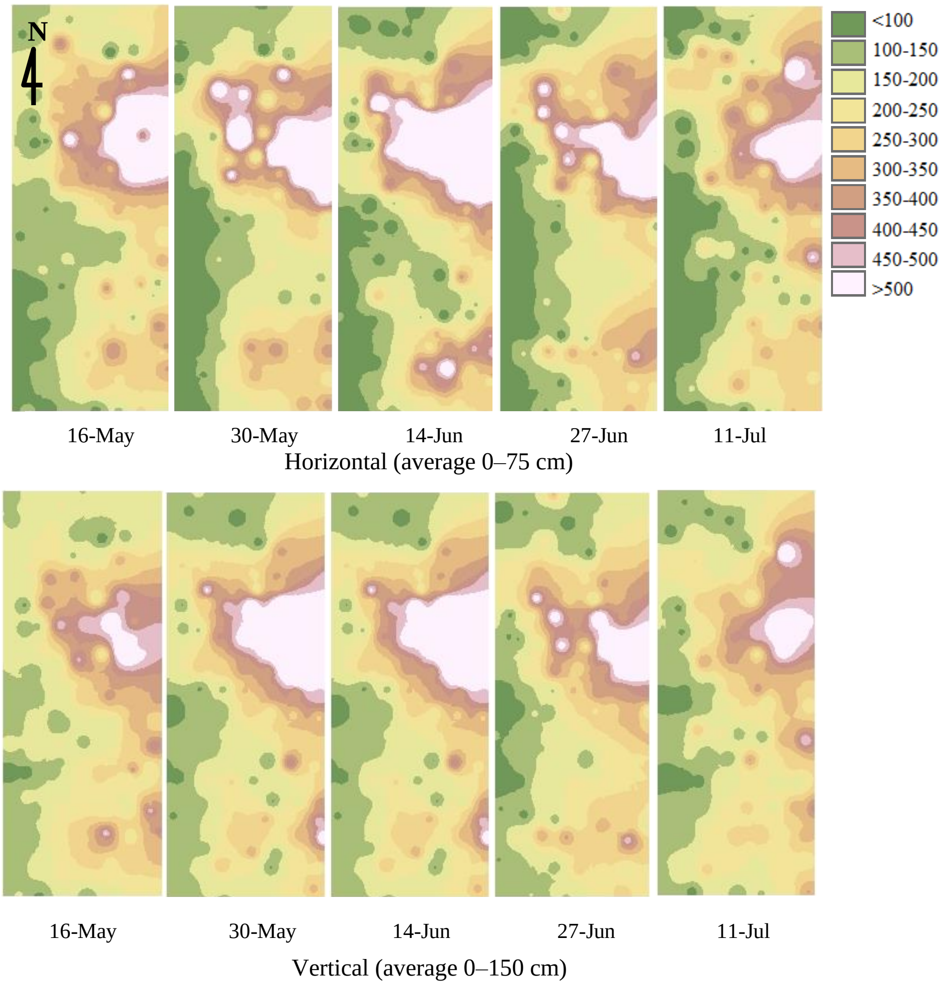

Fig. 3 Temporal and spatial distributions of soil apparent electrical conductivity (ECa)

CONCLUSION

A high-resolution investigation of soil ECa over a large area was conducted using the electromagnetic induction method. The ECa of two soil layers (0–75 cm and 0–150 cm depth) was measured and a soil salinization mechanism discussed. The results can be summarized as follows: (1) higher soil ECa was observed in the northern part of the study area near the swamp throughout the monitoring period, (2) the average soil ECa at a depth of 0–75 cm ranged from 233 to 282 mS/m, while it ranged from 236 to 268 mS/m between 0 and 150 cm, (3) the average soil ECa in upper layer was slightly higher than that of the lower layer in May, but the difference between them was reduced over time and the situation reversed in mid-July, and (4) a larger spatial distribution was observed for the upper layer compared with the lower layer, judged by the difference of the CV of the soil ECa. Soil salinization during the wet season was clearly observed. A comprehensive analysis of the soil salinization process, considering the fluctuation of the groundwater level, rainfall, and microtopography is planned for the future.

ACKNOWLEDGEMENTS

This work was supported by JSPS KAKENHI Grant Numbers JP17H04630 and International Platform for Dryland Research and Education, Tottori University.

REFERENCES

FAO. 2002. Agricultural drainage water management in arid and semi-arid areas. Rome, Italy: FAO Irrigation and Drainage Paper 61. Retrived from http://www.fao.org/docrep/005/y4263e/y4263e00.htm#Contents

Hanchai, S., Iwai, C.B., Topark-Ngarm, B. and Bunterng, P. 2010. Soil biota activities relation with soil characteristics in the improved salt-affected area by tree plantation. International Journal of Environmental and Rural Development, 1 (2), 54-57.

Kume, T., Nagano, T., Watanabe, T. and Mitsuno, T. 2003. Salinity measurement of homogeneous soil using electromagnetic induction method. Transaction of JSIDRE, 22, 105-111. (in Japanese)

Kume, T., Yamamoto, T., Shimizu, K. and Jalaldin, A. 2015. Non-uniform distribution of soil salinity along a transect of an irrigation field in an arid region. International Journal of Environmental and Rural Development, 6 (1), 181-187.

Pongwichian, P., Kohno, E., Kingshuk, R. and Sasada, K. 2013. Actual situation of management and future problems of reclamation on inland salt-affected soils in Thailand. Environmental Information Science, 27, 305-310.

Tatsuno, J., Hashimoto, Y., Tajima, K., Oishi, T., Dissataporn, C., Yamclee, P. and Tamaki, K. 2005. Reclamation of saline soil in northeastern Thailand using a solar-powered pump to control groundwater levels. Environ. Control Biol., 43 (3), 155-163.

Topark-Ngarm, B., Patcharapreecha, P., Goto, I. and Kimura, M. 1990. Studies on saline soils in Khon Kaen region, northeast Thailand, II. Seasonal changes of physical and chemical properties. Soil Sci. Plant Nutr., 36 (2), 289-298.

Santos, V.R.N. and Porsani, J.L. 2011. Comparing performance of instrumental drift correction by linear and quadratic adjusting in inductive electromagnetic data, Journal of Applied Geophysics, 73, 1-7.

Wongsomsak, S. 1986. Salinization in northeast Thailand. Southeast Asian Studies, 24 (2), 133-153.

Zukemura, C., Haraguchi, N., Miyamoto, T. and Nakaya, T. 2016. Determining high salinity soil layers depth using electromagnetic induction sensor EM38-MK2. IDRE Journal, 301, I_23-I_30. (in Japanese)