Evaluation of the Relationship between Electric Conductivity and Spectral Index for Soil Salinity Mapping of Rice Paddy Field in Khon Kaen Province

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Abstract*— Geospatial information about salt injury is required for rice growth management in Khon Kaen. However, the soil salinity map which is effective for rice growth management in Khon Kaen does not exist. As the first step, evaluation of the relationship between electric conductivity (ECe) which is the indicators of salt injury before planting and leaf area index (LAI) during growth period was conducted in this study. Soil samplings for measuring ECe before planting were conducted in Khon Kaen on 6th and 7th April 2016. To generate geospatial map of rice growth condition during growth period, Spectral measurement using drone and field measurement of LAI were conducted in the same area on 7th September 2016. As the results, it was confirmed that LAI during growth period and ECe before planting had negative correlation. Secondly, evaluation of the relationship between ECe and spectral index was performed for mapping the spatial distributions of ECe in the study area. Soil samplings for measuring ECe in the study area were conducted on 22nd December 2016 and 11th May 2017. Spectral measurements using drone for calculating normalized difference salinity index (NDSI) were executed on the same days. As the result, EC and NDSI obtained on 11th May 2017 had strong positive correlation compared to the one obtained on 22nd December 2016. These above mentioned results indicate that soil salinity map derived from NDSI image on the end of dry season has the potential to give the effective information for rice growth management.

Keywords*— *salt affected soil, soil salinity mapping, remote sensing

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I. INTRODUCTION

Salt affected soil is widely distributed in Northeast Thailand. Salt affected soil causes low rice productivity. There is salinity map in this region. In the map, the degree of salt injury is classified into 4 classes based on percentage of salt crust on soil surface (class 1: salt crust > 50%, class 2: 50% > salt crust > 10%, class 3: 10% > salt crust > 1%, class 4: 1% > salt crust > 0%). This map does not directly indicate the degree of salt injury because the one is not based on physical factors for evaluating salt injury. Therefore, in order to manage rice growth in Northeast Thailand, geospatial distribution map that is based on physical factors for evaluating salt injury is required. Electric conductivity (ECe) is very important indices for evaluating crop growth. However, the methodology to create the map of ECe in the study area does not exist.

In this study, as the first step to develop the methodology, evaluation of relationship between ECe before planting and amount of rice body above ground surface during growth period was conducted to confirm the influence of ECe before planting on the rice growth. And then evaluation of relationship between ECe and major soil salinity index obtained from spectral information was conducted to confirm the availability of spectral index for geospatial distribution mapping.

II. METHODOLOGY

In order to evaluate the relationship between ECe before planting and rice growth during growth period, soil sampling for ECe measurement (6 points) was conducted in Ban Phai in Khon Kaen province (Fig. 1) during 6-7 Apr. 2016 (before planting). The study area is categorized to class 2 in existing salinity map. Landscape of the study area is shown in Fig. 2. It can be confirmed that vegetation and salt crust are mixed. Measurement of the amount of rice above ground surface (36 points) was conducted in same region during 6-8 Sep. 2016 (during growth period). In this study, Leaf Area Index (LAI) was used as the indicator of amount of rice above ground surface. At the same time, multi-spectral images were obtained by multi-spectral camera (Sequoia, Parrot) attached to drone (Solo, 3DR). Spatial resolution of multi-spectral image was 5cm by 5cm per pixel. LAI of rice was measured by canopy analyzer (LAI-2200, Li-Cor).

Fig. 1. Location of study area.

Fig. 2. Landscape of study area.

In this study, Green-Red ratio Vegetation Index (GRVI) [1], [2] was used for estimating rice LAI because the one was the best index for estimating LAI compare to other vegetation indices (Simple Ratio (SR), Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index 2 (EVI 2), Red edge Chlorophyll Index), and NDRE (Normalized Difference Red Edge (CIred_edge)) in the study area. These vegetation indices were derived from multi-spectral camera data during Sep. 6-8 2016. GRVI is calculated using the following formula.

$$GRVI = (\mathrm{GREEN} - \mathrm{RED}) / (\mathrm{GREEN} + \mathrm{RED}) \quad (1)$$

where GREEN and RED in (1) indicate reflectances of wavelength in green and red, respectively. Then LAI values at the soil sampling points for ECe measurement were estimated by using the regression equation between LAI and GRVI obtained from field survey. And the relationships between ECe before planting and LAI during growth period were evaluated.

In order to estimate ECe by using spectral index, multi-spectral images were obtained on 22 Dec. 2016 and 11 May 2017. Spatial resolution of these images were also 5cm by 5cm per pixel. Soil sampling for ECe that were used for comparing to spectral index were conducted on the same day. Furthermore, Soil Moisture Content (SMC) measurements was conducted at the same points on the same day because it is considered that soil water also affect to spectral information. Normalized Difference Salinity Index (NDSI) [3] was selected for estimating ECe in this study. This spectral index has been used as the one of major index for estimating degree of salinity injury in the world [3], [4]. NDSI is calculated using the following formula.

$$NDSI = (\mathrm{RED} - \mathrm{NIR}) / (\mathrm{RED} + \mathrm{NIR}) \quad (2)$$

where RED is the same one in (1). NIR is reflectance of wavelength in near-infrared. After obtaining NDSI images from multi-spectral images, the relationships between ECe and NDSI on 22 Dec. 2016 and 11 May 2017 were evaluated. And then the relationships between SMC and NDSI, and the one between ECe and SMC on the same days were evaluated for understanding the difference of the relationships between ECe and NDSI on each day. Field survey for ECe and SMC measurements for evaluating the above-mentioned relationships was conducted at 8 points on each day.

III. RESULT AND DISCUSSION

A. Evaluation of the relationship between ECe before planting and LAI during growth period

As the results of evaluation of the relationships between LAI derived from GRVI image and ECe, it is confirmed that LAI and ECe had negative correlation (Fig. 3). This means that ECe concentration before planting affect to the rice growth. Therefore, it is considered that geospatial distribution map of ECe before planting (in dry season) is very useful for suitable rice growth management.

B. Evaluation of ECe and NDSI in dry season

To generate geospatial distribution map of ECe, the relationships between NDSI derived from multi-spectral images and ECe on 22 Dec. 2016 and 11 May 2017 were evaluated. As the results, both of the relationships between ECe and NDSI on 22 Dec. 2016 and the one on 11 May 2017 had positive correlation (Fig. 4 and Fig. 5). Correlation coefficients on 22 Dec. 2016 and 11 May 2017 were 0.76 and 0.83, respectively. Although the correlation coefficient on

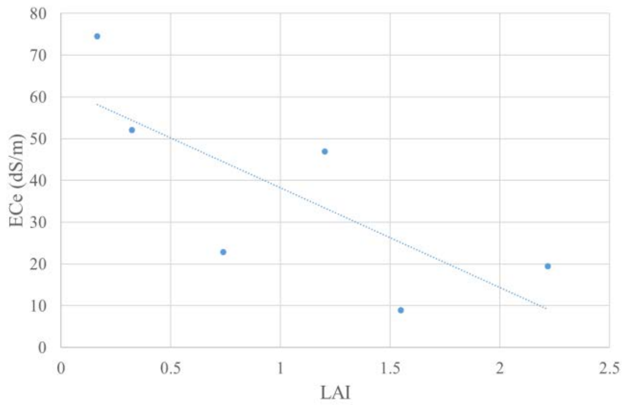

Fig. 3. Relationship between ECe before planting and LAI during growth period.

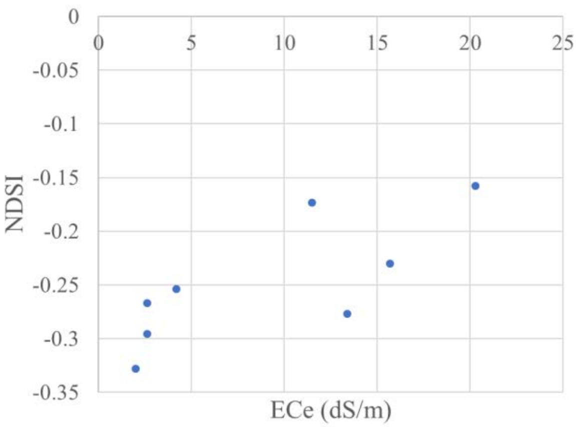

Fig. 4. Relationship between ECe and NDSI on 22 Dec. 2016.

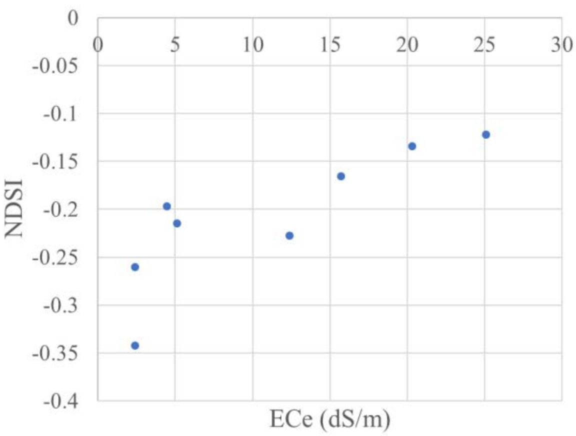

Fig. 5. Relationship between ECe and NSDI on 11 May 2017.

each day had positive value, the one on 11 May 2017 had stronger correlation than the one on 22 Dec. 2016. To understand the difference in these correlation coefficients, firstly SMC on each day was compared. And then both of relationships between NDSI and SMC on 22 Dec. 2016 and 11 May 2017 were evaluated. And relationships between ECe and SMC on each day were also evaluated.

Average values of SMC on 22 Dec. 2016 and 11 May 2017 were 15.9% and 10.7%, respectively. SMC value on 22 Dec. 2016 was higher than the one on 11 May. The correlation coefficients between SMC and ECe on each day was -0.36 and 0.71, respectively. It seems that the difference in SMC value affect to the relationship between SMC and ECe. In other word, relationship between SMC and ECe has positive correlation when SMC value is high. However, the one has negative or no correlation when SMC value is low. Figure 6 and 7 show the relationships between NDSI and SMC on 22 Dec. 2016 and 11 May 2017, respectively. Correlation coefficients on 22 Dec. 2016 and 11 May 2017 were -0.01 and 0.37, respectively. From above-mentioned results, the following findings were obtained at the study area.

- There is no correlation between NDSI and SMC when SMC value is relatively high and there is negative correlation between ECe and SMC.
- However, there is positive correlation between NDSI and SMC when SMC value is quite low and there is strong positive correlation between ECe and SMC.
- There is positive correlation between ECe and SMC when SMC value is quite low.

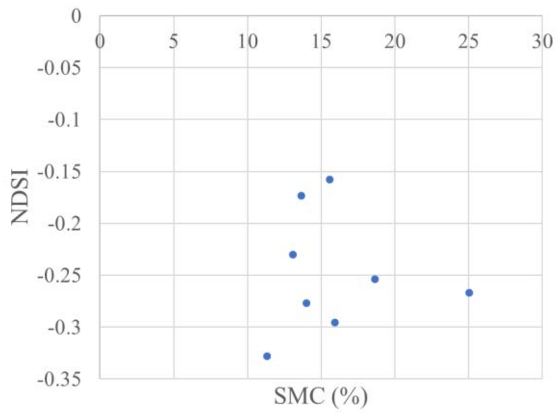

Fig. 6. Relationship between SMC and NDSI on 22 Dec. 2016.

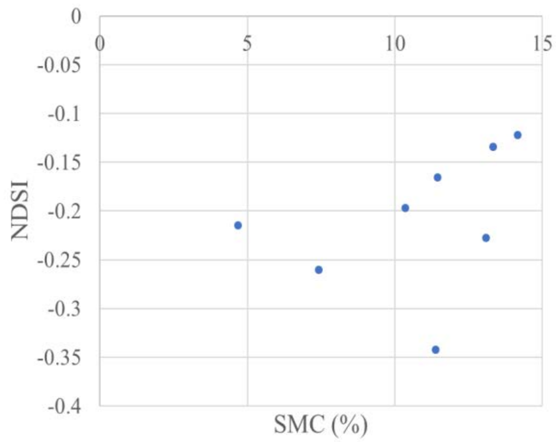

Fig. 7. Relationship between SMC and NDSI on 11 May 2017.

- There is weak negative correlation between ECe and SMC when SMC value is relatively high.
- NDSI has the potential to estimate ECe when SMC value is quite low and there is positive correlation between ECe and SMC.

IV. Conclusion

In this study, in order to develop the methodology of mapping the spatial distribution of salt injury, evaluation of relationship between ECe before planting and amount of rice body above ground surface during growth period was firstly conducted. And the influence of ECe before planting on the rice growth was confirmed. As the result, it is confirmed that ECe before planting (in dry season) affects to the rice growth at the study area. And then evaluation of relationship between ECe measured by field survey and NDSI obtained from spectral information was conducted to confirm the availability of NDSI for geospatial distribution mapping of salt injury using remotely sensed data. In this study, it was confirmed that NDSI could estimate ECe value. However, the result was obtained when SMC value was low and SMC had strong positive correlation with ECe. And it was also confirmed that the relationship between SMC and NDSI changed when the relationship between SMC and ECe changed. Influence of SMC to estimate ECe using NDSI was small in this study. However, it is considered that SMC will affect to NDSI value for estimating ECe depends on the situation. Therefore, to develop the robust estimation method of ECe value using spectral index such as NDSI, the influence of soil moisture condition will be evaluated under several areas and conditions in the future study.

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