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SUMMARY OF DOCTORAL THESIS

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Title: Hyperspectral remote sensing of soil salinity in Minqin oasis, China
(中国民勤オアシスにおけるハイパースペクトルリモートセシングを用いた土壌塩分の推定)

Dryland salinity is the most common type of land degradation encountered in natural resource management in many semi and arid land of the world and has received much attention from farmers, politicians and researchers. As one of the primary inhibitors of crop yield and ecological functions, soil salinity might ultimately lead to environmental disaster and food crises in arid regions. Soil salinization is a serious ecological and environmental problem because it adversely affects sustainable development worldwide, especially in arid and semi-arid regions. Soil salinization in China occurs mainly in arid and semi-arid areas in the north-western region, where low precipitation is coupled with intensive evaporation and ineffective irrigation drainage systems have resulted in secondary salinization. The semi-arid and arid land in China are mainly in Northwest region and the area of salt-affected soils counts about37.4% of total area of salt-affected soil.

Minqin Oasis, the study area, is located in the lower reaches of an inland river of northwest China, suffers a great shortage of fresh water for agriculture because of the low rainfall and massive demand for water created by increased agricultural activity and rapid population growth. Soil salinization and water resource deterioration negatively affect the local irrigated agriculture semi-arid areas by limiting the area of arable land and reducing crop yields. Groundwater has been over-exploited to fill the gap between surface freshwater supply and demand. Groundwater extraction provides short-term relief from the scarcity of water for agricultural and domestic use, but excessive extraction lowers the water table and increases salt concentrations in groundwater. Long-term agricultural use of saline water has led to a rapid increase of secondary salinization, which also led to land abandonment and threaten the crop production and agriculture system. Damage to the environment has been extensive, and represents a serious threat to the sustainability of social and economic development in the Minqin Oasis.

Monitoring and accurate estimates of the areal extent of salinized land and prediction of salt-affected areas are essential for policy makers, planners and farmers to allow effective management of irrigated land, control of salinization and reversal of current trends of soil and water degradation, and achieve sustainability of agriculture.

However, the conventional methods of monitoring salinity by using ground-based geophysical techniques are time-consuming and costly. Multispectral data has been used widely for capture the salt-affected area. However, due to limited spectral resolution, it is difficult to classify the non-saline and slightly-saline soils. Hyperspectral remote sensing techniques has been used to detect soil salinity and monitor soil salinization efficiently and widely with high spectral resolution and range. It can capture the spectral characteristics (peak and absorption) of salts for characterizing soil salinity and distinguishing different levels of soil salinity.

Therefore, the aim of this thesis is to develop predictive models for quantifying salts content in soils on the basis of the using of soil hyperspectral reflectance and field survey in Minqin oasis. The specific objectives are: (a) to qualitatively mapping the salinity and analyzing its casual factors; (b) to quantitatively estimate soil salinity by modeling from lab-measured spectral reflectance data; (c) to quantitatively estimate soil salinity by modeling from field-measured spectral reflectance data.

This study comprises five chapters (1-5) described as follows:

The chapter 1 presents the introductory section of this study. It sets out an overview of the background for the study, focusing on the adverse effect of soil salinization problems, review of previous researches related with monitoring salinization technology (conventional and advanced modern technology), literary review and the methods that used to salinization detection and prediction. Subsequently, it presents the study objectives and organization of the thesis.

The chapter 2 analyzes of the spatial variation of soil salinity and its causal factors. We obtained 94 surface soil samples to a depth of 10 cm from unused land (9 samples from shrubland, 5 samples from abandoned land, 46 samples from sparse grassland, 13 samples from saline wasteland) and cropland (used to grow wheat, sunflower, alfalfa, goji berry, and fennel). The saline-alkaline land were mainly concentrated in the margin of oasis without human intervention (affected by micro topographic and hydrological factors). Secondary salinized land mainly located in the long-term abandoned land inside the oasis. Land-use practices had a crucial influence on the distribution and accelerating soil salinization. Through the grey relation analysis among soil salinity and other possible casual factors include underground water table, distance to irrigation cannels, topography index and vegetation coverage. The distance to irrigation cannels has been identified as the key casual factor for salinization, which indicated that access to the fresh irrigation water resource is the key factor for improving salinization in Minqin.

The chapter 3 derives the salt content in salinized soil from hyperspectral reflectance data which has a full wavelength (350nm-2500nm) and measured in lab-condition for Minqin oasis. Lab-condition ignored the soil water moisture and atmospheric factors that could lead to noise in reflectance. During April 2015 we collected surface soil samples (0–10 cm depth) at 64 field sites of Minqin Oasis undergoing NaCl and $CaSO_4$ salinization. We used a normalized difference spectral index of salinity that integrates any two randomly selected hyperspectral bands to obtain all possible waveband pairs that might be associated with the salts contributing to salinization. Correlation analysis of the indexes obtained for all of the possible waveband pairs with the wavebands corresponding to the measured soil salinities showed that two bands centered at 2382 and 1358 nm were closely associated with sodium and chloride concentrations. We applied linear regression modelling to these bands to construct a soil salinity index. Validation of the index by correlation analysis of the index-derived salt contents with measured salt contents of 31 soil samples showed a strong correlation ($R^2 = 0.8272$). Thus, the model we derived successfully estimated the salt content of surface soils in the study area.

The chapter 4 derives the salt content in salinized soil from hyperspectral reflectance data which has a full wavelength (350nm-1000nm) and measured in field-condition that is different with lab-condition. Based on the correlation analysis with EC, the sensitive bands pair at 489 and 517 nm were selected successfully. The pre-process includes continuum-removed analysis and first derivation were separately applied to spectrum, and the results indicated that continuum-removed analysis give a better performance on removing noise of spectrum. In addition, based on the comparing between 2 different dataset, using the full wavelength spectra data obtained from laboratory measurement based on the pre-process of continuum-removed analysis would improve the ability to retrieve the soil salinity and perform better soil salts estimation.

Chapter 5 provides a general synthesis of the whole thesis and conclusions. Further research is needed on the application of this method to remotely sensed (aircraft or satellite) digital hyperspectral data so that its potential use for large-scale predictive mapping of the extent and severity of soil salinity can be investigated.