Research Progress of Remote Sensing Monitoring of Soil Salinization

Yanan Li¹,²,³,⁴,*

¹Shaanxi Provincial Land Engineering Construction Group Co., Ltd., Xi’an, China
²Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd., Xi’an, China
³Key Laboratory of Degraded and Unused Land Consolidation Engineering, the Ministry of Natural Resources, Xi’an, China
⁴Shaanxi Provincial Land Consolidation Engineering Technology Research Center, Xi’an, China

*Corresponding author e-mail: 930157635@qq.com

Abstract. It has become a trend to apply remote sensing technology to the monitoring of soil salinization to obtain soil salinization information. This article reviews the research progress in data selection, spectral feature indexes, and retrieval methods in soil salt monitoring by remote sensing. The study pointed out that with the development of 3S technology, remote sensing technology has broad application prospects in soil salinization monitoring. The combination of remote sensing and electromagnetic induction technology, as well as the collaborative inversion of soil salinity from multi-source remote sensing data, and the construction of regional, national or global scale monitoring models will be the future development research direction of soil salinity monitoring.

1. Introduction

In a narrow sense, saline soil refers to the soil with high salt content and difficult for plants to grow. The alkaline soil, saline soil, various saline soils and various salinized and alkaline soils widely distributed in a certain area are saline-alkaline soils in a broad sense[1]. According to relevant statistics from the Food and Agriculture Organization of the United Nations (FAO) and UNESCO (UNESCO), the area of saline-alkali soil worldwide is about 954 million hm²[2], and the total area of saline soil in my country has reached nearly 100 million hm²[3].

Traditional soil science and agronomy monitor and control soil salinity and the degree of salinization are mainly limited to the field and small-scale areas. Generally, the determination of soil salinity needs to be collected by drilling in the field, and then collected. The samples are analyzed in the laboratory, which is time-consuming, labor-intensive and costly. With the development of remote sensing technology, it is possible to analyze and estimate the condition of soil characteristic parameters in a large area. Accurate grasp of the distribution of soil salinity at the regional scale is beneficial to the real-time monitoring of regional saline land, and is a prerequisite for the ecological restoration of regional saline soil. Remote sensing technology has the characteristics of large regional
scale and high time resolution, which provides a convenient and quick way to monitor soil salinity on a regional scale, especially in the monitoring and mapping of saline-alkali soils.

2. Data selection
At present, the commonly used remote sensing data for soil salinity monitoring include: Terra, Mss, TM, ETM+, Quickbird, ASTER, SPOT, RADARSAT, IRS and other satellite remote sensing data and HyMap, AME and other satellite remote sensing data. Although remote sensing analysis methods are gradually increasing, visual interpretation is still the main method for soil salinization dynamic monitoring. Compared with previous research results, the current research content is more abundant and extensive, and it is transitioning from the original static qualitative research to dynamic quantitative research.

3. Spectral characteristic index
The original reflectance spectrum is often disturbed, and it often cannot directly reflect the relationship between the spectrum and the soil salt content. Therefore, in practice, the transformation form of the original spectrum is often used as the spectral characteristic index reflecting the change of soil salinity. The transformation form mainly includes the mathematical operation of the spectral shape characteristic parameter and the spectral index.

3.1. Spectral shape feature and its calculation form
Reflectance is widely used in soil salt monitoring. The spectral reflectance of saline soil is greater than that of other types of soil. There is a good linear relationship between the spectral curve and the soil salt content. The higher the salt content, the stronger the spectral reflectance. Under normal circumstances, saline soil is more sensitive in the red light band and near-infrared band. At present, many scholars use the calculation form of the original spectrum as the spectral characteristic index. The calculation form mainly includes algebraic operations and differential operations. The algebraic operations mainly include taking the logarithm, the reciprocal, the logarithm of the reciprocal, the reciprocal of the logarithm, and the average of the original spectrum. Square root; differential operations include first-order and second-order differentials. The first-order differential forms have one-order derivative, root-mean-square first-order derivative, log first-order derivative, reciprocal first-order derivative, and first-order derivative of reciprocal logarithm. The second-order differential forms include second-order differential, second-order differential of logarithm and second-order differential of reciprocal of logarithm. A large number of studies have shown that the correlation between the soil emissivity spectrum and the measured salt data will change after mathematical transformation. Some researchers have correlated the above-mentioned spectral transformation form with the measured soil salinity data and found that the first derivative and the logarithmic second-order differential transformation have a good correlation with the soil salt content.

3.2. Spectral Index
The inversion and monitoring of soil salinity information using the feature space constructed by various spectral indices in remote sensing images is the current frontier method of soil salinity remote sensing monitoring research. Currently commonly used are drought index, vegetation index, salinity index, brightness index, humidity index, water index, composition index, clay index, etc., Different spectral indices include many forms, such as: vegetation index includes normalized vegetation index, enhanced vegetation index, soil regulation vegetation index, generalized vegetation index, etc.; salt index SI includes normalized salt index, SI1, SI2, SI3, canopy response salinity index, etc.
### Table 1. Vegetation index used to evaluate soil salinity

| Vegetation index                        | formula                                      | years | research area                        | references |
|-----------------------------------------|----------------------------------------------|-------|--------------------------------------|------------|
| Normalized vegetation index             | $\text{NDVI} = \frac{(\text{NIR} - R)}{(\text{NIR} + R)}$ | 2007  | Yanqi Basin in Western China          | [4]        |
| Enhanced vegetation index               | $\text{EVI} = 2.5 \times \frac{(\text{NIR} - R)}{(\text{NIR} + 6R - 7.5B + 1)}$ | 2009  | The border between Minnesota and Dakota | [5]        |
| Soil regulation Vegetation index        | $\text{SAVI} = \frac{(\text{NIR} - R)(1 + L)}{(\text{NIR} + R + L)}$ | 2014  | Al-Hassa Oasis in Saudi Arabia        | [6]        |
| Generalized vegetation index            | $\text{GDVI} = \frac{(\text{NIR}^n - R^n)}{(\text{NIR}^n + R^n)}$ | 2014  | Dujaila in Iraq                       | [7]        |
| Extended normalized vegetation index    | $\text{ENDVI} = \frac{(\text{NIR} + \text{SWIR}_2 - R)}{(\text{NIR} + \text{SWIR}_2 + R)}$ | 2015  | Yellow River in China delta           | [8]        |
| Extended enhanced vegetation index      | $\text{EEVI} = 2.5 \times \frac{(\text{NIR} + \text{SWIR}_2 - R)}{(\text{NIR} + \text{SWIR}_2 + 6R - 7.5B + 1)}$ | 2015  | Yellow River in China delta           | [8]        |

Note: $L$ is the soil adjustment coefficient, taking 0.5.

### Table 2. Salt index used to evaluate soil salinity

| Salt Index                          | formula                                      | years | research area                  | references |
|-------------------------------------|----------------------------------------------|-------|--------------------------------|------------|
| Salt Index                          | $\text{SI} = B \times R$                     | 2005  | Punjab Province, Pakistan      | [9]        |
| Normalized salt index               | $\text{NDSI} = (R - \text{NIR})/(R + \text{NIR})$ | 2005  | Punjab Province, Pakistan      | [10]       |
| Salinity Index 2                    | $\text{SI}2 = \sqrt{G^2 + R^2 + \text{NIR}^2}$ | 2006  | Lower Cheliff Plain, Algeria   | [11]       |
| Salinity Index 3                    | $\text{SI}3 = \sqrt{G^2 + R^2}$              | 2006  | Lower Cheliff Plain, Algeria   | [12]       |
| Salinity Index 4                    | $\text{SI}4 = (R/\text{NIR}) \times 100$    | 2007  | Kanpur near the Ganges Plain, India | [13]       |
| Canopy response Salinity index      | $\text{CRSI} = \frac{(\text{NIR} \times R) - (G \times B)}{\sqrt{(\text{NIR} \times R) + (G \times B)}}$ | 2015  | Central Valley in California    | [14]       |

### 4. Inversion method

Most methods of constructing inversion models use statistical methods. In addition to traditional linear regression, exponential regression, and multiple stepwise regression, other advanced statistical and machine learning methods such as partial least squares regression analysis, BP neural networks, and support vector machines are also widely used in the inversion of soil salinity. From the current point of view, various modeling methods are compared and analyzed, and finding an inversion model with better stability and higher accuracy is the direction that many scholars need to study hard.

The multiple linear regression model can accurately measure the degree of correlation between various factors and the degree of regression fitting. It is a relatively conventional modeling method in the inversion of soil salinity. When the number of variables is much larger than the number of samples, the introduction Partial least squares regression method of principal component analysis idea. Studies
have shown that the partial least squares regression analysis method reduces the dimension of spectral data and improves the efficiency of analysis on the basis of ensuring the maximum amount of information. Studies have shown that the soil salt prediction model established by partial least squares regression has good inversion accuracy. In addition, the application of BP neural network and support vector machine in soil salt remote sensing monitoring is also attracting attention. Due to the influence of plants, water, and soil systems, the spatial distribution of soil salinity and backscattering characteristics have a complex nonlinear function relationship. The neural network is based on the method of nonlinear function approximation theory. Its mature BP technology can be The study of nonlinear function approximation in soil salinity monitoring by remote sensing provides a new way of thinking and modeling. Studies have shown that in the remote sensing inversion of salinity in saline soil, the BP neural network has higher accuracy than the multiple linear regression method, but the BP neural network has slower convergence speed, local minima, and no theoretical support for structure determination. Disadvantages. The support vector machine method is based on the principle of structural risk minimization. The statistical learning theory of the theorems of convergence speed and generalization error, from linear separable to linear inseparable, a new type of machine learning method that only considers input and output, can better solve local minima, nonlinearity and Practical issues such as high dimensionality. Studies have shown that support vector machines have significantly improved model accuracy compared to multiple linear regression and BP neural networks.

5. Conclusion and Outlook
Although the remote sensing inversion of soil salinity has achieved certain research results, there are still the following problems: (1) It is mainly to analyze the surface salt of the soil, and the salt dynamics of the overall profile are less involved; (2) The model research scale is mainly regional, The establishment of a unified quantitative inversion model of soil salinization at the national or even global scale is rarely involved. At present, combining remote sensing technology with electromagnetic induction is a new method for monitoring soil salinity. To this end, further explorations can be made from the following aspects: one is to further discover and improve the spectral feature index highly related to soil salinity, and to improve the accuracy of model prediction; the other is to target different land cover/use patterns, soil moisture, and groundwater. Buried depth and soil type further study the possibility of using remote sensing data to predict soil salinity; third, combining remote sensing and electromagnetic induction technology to study the characteristics of temporal and spatial variation of soil salinity; fourth, establishing a unified quantitative inversion of soil salinity on a national and even global scale Model to meet the needs of large-area monitoring.

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