An Empirical Method for Soil Salinity and Moisture Inversion in West of Jilin

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Abstract—**Soil salinization has been known as a world wide problem. It is a chemical process that causes soil degradation particularly in arid and semi-arid agriculture region. There both advantages and disadvantages of optical and microwave remote sensing in the recognition of salinization soil. In order to retrieve both soil salinity and moisture, an empirical method is presented in this paper which is combined optical, microwave remote sensing and ground-based data. Based on the analysis of the relationship between SAR backscatter, NDVI and soil salinity and moisture, a multiple linear regression is used. The RMSE of soil salinity and moisture are 3.175g/Kg and 3.169% respectively. The results demonstrate that combing microwave and optical remote sensing are suitable for inversion salinity and moisture content in salinization soil, however, methods based on theory knowledge need to be proposed in further research.**

Keywords—Soil salinity; moisture content; RADARSAT-2; microwave; inversion.

I. INTRODUCTION

Soil salinization is the main land degradation problem in arid and semi-arid agriculture region, and it is essential to monitor salinity information dynamically and accurately in time for further land degradation and agricultural sustainable development. At present, soil salinization has been known as a worldwide problem. Soil salinization of irrigation area is developing at an amazing speed, and there is about $10hm^2$ of arable land loosed per minute while 30% of them is caused by salinization [1], [2].

The salinization soil has a wide distribution in China which covers the cold temperate, tropical zone, coastal and inland also with the lowlands and plateau. Northeast of China is one of the most important areas for production of grain and the guarantee of food security in the country. One of the most important approaches to achieve food production is the improvement of salinization soil. The salinization soil of Songnen plain is about 56 million acres which one of the three world's sodium salinization soil and west of Jilin province accounts for more than 24 million acres [3]. Therefore, it is essential to develop suitable methods for the monitoring of salinization soils. The traditional field positioning observation can only be from point measurement to line and then extended to area, which are boring and time and money consuming. Many techniques based on spectral remote sensed data are used for mapping and tracking the evolution of soil salinity quickly and on a large area. The discrimination between salt-affected and non-affected soils can easily be carried out using the visible and infrared wavelengths, except over coastal areas, black-clay soils, and desert areas, due to the smoothness and the white color of the formed crust [4]. However, in the microwave wavelengths, the signal is sensitive to the dielectric properties of the target [5]. Studies have shown that, change of soil moisture and salinity will affect the conductivity of soil and then influence soil dielectric constant, further more direct impact on the target backscatter coefficient of radar imagery or brightness temperature of microwave radiation. Theoretically, radar data have great potential for evaluating soil salinity for the monitoring and eventually, the mapping of salt-affected areas [6]. However, microwave signals are often affected by the surface roughness and vegetation, while optical remote sensing is sensitive to vegetation information. So the synergy of optical and microwave remote sensing is an important direction of the development for remote sensing inversion. In this paper, our objective is to combine optical and microwave remote sensing and try to find a better way of soil salinity and moisture quantitative retrieval based on ground-based observations, while the optical data is from HJ-1CCD and microwave data from RADARSAT-2. Based on empirical statistical model to determine the feasibility of combine optical and microwave remote sensing data.

II. STUDY AREA AND MEASUREMENTS

A. Location

The study site is in part of Da'an-west of Jilin province (45°20′N—45°35′N; 123°23′—123°44′), which belongs to the Songnen plain. The saline soil of Da'an is about $25 \times 10^4 hm^2$ and accounts for 51.5% of all the area which is given priority with moderate and strong soda salinization land. The soil salinization of Da'an is caused synthetically by various environment factors, such as climates, geology, parent material and vegetation, surface runoff and freezing and thawing in winter. Climate here belongs to semi-humid temperate continental monsoon climate. Mean annual rainfall is less than 400mm with 70-80% occurring during the summer period while evaporation is high to 1200mm. The quaternary environment provides into soil parent material, plus matrical sticky heavy, poor drainage by closed sinkage and shallow groundwater depth, all of which forming one of the world's largest soda saline and alkaline land area.

B. Available Data

HJ-1CCD image of June 22 2012 acquired over the study area is provided by China centre for Resources Satellite Data and Application with a resolution of 30 m and RADARSAT-2 SAR of June 28 2012 acquired with fully polarized detailed model （HH, HV, VH, VV ）provided by the Canadian Space Agency with a resolution of 12.5 m in range by 8 m in direction and C-band of 5.4GHz. These two kinds of data are almost acquired synchronously. The optical image is carried on atmospheric radiation correction and geometric correction. The radiation calibration and filtering processing were done before geometric correction and then was resample into 30 m in order to match the optical image. We use HJ-1CCD optical data to get the NDVI of the study region.

Ground data collections have been conducted coincident with RADASAT-2 SAR data from June 26 to July 1. About 222 soil samples were collected at the 0-5 cm depth according to the salinization degree of surface soil. They were analyzed in laboratory in order to determine the physical (texture, density, soil moisture, etc) and chemical (anions, cationic, pH, etc) properties of the soils samplings. Table I summarizes the main properties of the soils over the study areas.

Surface roughness was measured surface roughness tester based on laser triangulation [7]. The average value of the rms height(s) and that of the correlation length (l) are 0.215 and 3.45 cm, which only on bare soils and low-vegetation covered areas.

TABLE I.   Main   properties of soil samples

Variables	Units	Mean	Min	Max	Median	St.D
Bulk	g/cm3	1.350	0.905	1.737	1.369	0.174
Moisture	0~1	0.147	0.046	0.369	0.143	0.052
Salinity	g/Kg	4.743	0.881	20.140	3.675	3.429
PH	/	9.362	7.120	10.690	9.685	0.889
EC1:5(25℃)	mS/cm	0.942	0.106	5.030	0.485	1.03509

III. METHOD AND RESULTS

A. Univariate Statistical Analysis of Salinity and Moisture

Establish the correlation analysis between image factors and salinity and moisture, then to find the most significant factor. The image factors which participate in the correlation analysis are qual-polarization radar backscatter coefficient (HH, HV, VH and VV) and NDVI which can stand for vegetation information. Formula of relevant coefficient shows in equation (1):

$$r_i = \frac{Cov(R,S)}{\sqrt{D(R)}\sqrt{D(R)}} = \frac{\sum_{n=1}^{N}(R_{ni}-\overline{R_i})(S_n-\overline{S})}{\sqrt{\sum_{n=1}^{N}(R_{ni}-\overline{R_i})^2\sum_{n=1}^{N}(S_n-\overline{S})^2}} \quad (1)$$

Where, N for the number of samples, R_{ni} for factor i of the nth sample, S for soil salinity or moisture. Analysis result shows in table 4. All the factors are significant related with soil salinity or moisture which the confidence level is 0.05. The sensitivity of each factor is almost the same, and all of them should be taken into consideration in the retrieval study

of salinity and soil moisture. The correlation coefficient is shown in Table II.

TABLE II. Correlation   analysis result

Factors	NDVI	HH	HV	VH	VV
r_i -salinity	-0.431	-0.647	-0.409	-0.526	-0.537
Sig.(2-tailed)	0.004	0.002	0.001	0.006	0.001
r_i -moisture	-0.477	-0.357	0.594	0.494	0.331
Sig.(2-tailed)	0.001	0.002	0.004	0.007	0.004
N	222				

B. Regression Analysis

For surface parameter inversion, the commonly used methods have statistical model based on empirical formula and physical model based on theory. Statistical model conducts a statistical description or correlation analysis for series of observation data based on the correlativity between terrestrial parameters and remote sensing data, and then constructs the regression equation of them. The advantage of this method is less parameters and easy to construct and also can be effectively summarized from local area data. This method also has disadvantage, such as geographical limitations and portability difference, incomplete theory basis and the lack of understanding and knowledge of physical mechanism. Compared with empirical model, physical model has definite physical meaning and attempts to make a mathematical description of action mechanism while also need too many parameters to support the theory model continue.

1) Construction of Regression Equation: In the last section, the statistical analysis shows the sensitivity between image parameters and salinity and moisture. The regressions are performed between radar images, NDVI and soil-sample salinity and moisture. There are 12 unknown numbers while 222 known numbers to build an over-determined system which almost is a equation without solution. A least squares method was used to solve the problem here. The regression equations about salinity and soil moisture content describe in equation (2) and (3) respectively, where S is the soil-sample salinity and σ_{pq}(p, q for H or V) is the RADARSAT-2 SAR data in Qual-polorization is the   for, S in stand for salinity and M for Moisture content ,the results of a_i and b_i shows in Table III. The RMSE is 3.175g/Kg for salinity retrieval while 3.169%for moisture content.

$$S=a_0+a_1*\sigma_{hh}+a_2*\sigma_{hv}+a_3*\sigma_{vh}+a_4*\sigma_{vv}+a_5*ndvi \quad (2)$$

$$M=b_0+b_1*\sigma_{hh}+b_2*\sigma_{hv}+b_3*\sigma_{vh}+b_4*\sigma_{vv}+b_5*ndvi \quad (3)$$

2) Inversion-Measured-Sample Comparison: The relationship observed between inversion and measured salinity is shown in Fig.1, which salinity inversion is expressed in equation (2) and the moisture in Fig.2 with equation (3).

The results show a good relationship between the inversion data and measured data. ①For salinity inversion

in Fig.1, there is an underestimate while the sample has high salinity content and an overestimate in place which has low salinity, which shows in the ellipse A and B respectively. ② For moisture content inversion in Fig.2, the data is underestimated while the moisture content of samples are higher than 15% and overestimated while are 5% more or less, which shows in the ellipse A and B respectively also.

TABLE III. REGRESSION RESULT OF SOIL SALINITY AND MOSITURE

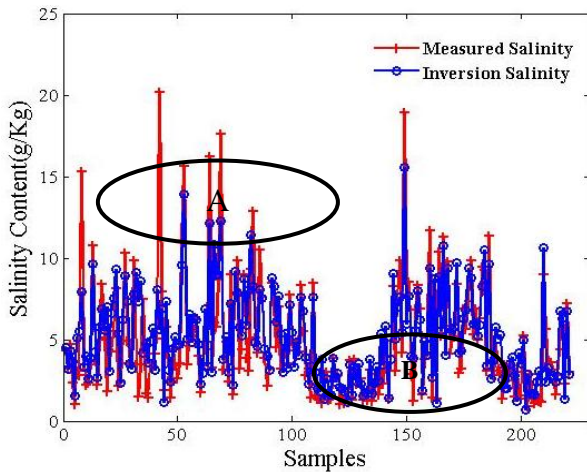| a_i	a_0	a_1	a_2	a_3	a_4	a_5
data	2.44	-0.145	0.017	0.046	-0.098	-1.46
b_i	b_0	b_1	b_2	b_3	b_4	b_5
data	16.2	-0.06	0.12	-0.4	-0.09	-11.9

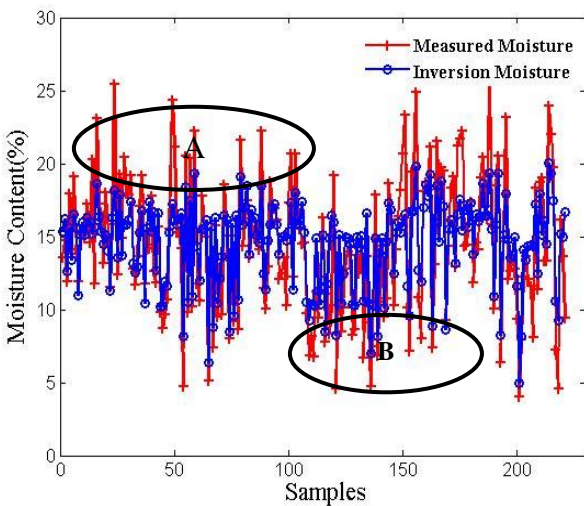Figure 1. Inversion and Measured Salinity

Figure 2. Inversion and Measured Moisture Content

IV. CONCLUSION AND DISCUSSION

Soil salinity is an important environmental socio-economic problem, especially in Northwest of China which is one of the most important grain-producing area in China. The result gained from optical reomte sensing to monitor the affected areas may be effictive in many areas, except over coastal areas, black-clay soils,and desert areas,due to the bright of the formed crust. However, to evaluate quantitatively the salinity content of such areas are very poor, and also can not gain the moisture content in the mean time. In microwave, especially in radar, only a few investigations focused on this topic.Using modeling of combining optical and radar images, we can obtain the inversion results of soil salinity and moisture and the paper show it is feasible to use multi-source romote sensing data in salinity and moisture retrival of salinization soil. However, there may be overestimated in low salinity and moisture and lowestimated in high salinity and moisture. The main reason for overestimation of salinity is that vegetation has greater impact in low salinity areas and the roughness is higher than most of salinity soils in salinization soil of west of Jilin, while the reason of a lowestimation is that salt dissolved inadequate without enough soil mositure which results to adsorbing of salt ionics on the surface soil particles and reduces the electrical conductivity. The main errors for moisture are vegetation and surface roughness. In this paper, although only a emperical model is proposed to inverse soil moisture and salinity, without theory equation introduced, it is a starting piont for the development of combination multi-source remote sensing data to salinization soils. Many severer salinization areas have smoothness surface, but this is not suitable for the whole area. Further investigations based on theory and considered about roughness look hopeful.

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