Correlation between salinity and crack characteristic of saline soil in Songnen plain

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***Abstract*—Effective improvement of saline-alkali soil is very significant for the yield and the ecological environment, thus accurate parameters of different saline-alkali soils are deeply required. In this paper, the areas and perimeters of different soil cracks are detected in a non-contact, non-invasive online way by the three-dimensional laser imaging technology and several common texture feature measures are also derived from GLCMs of different soil crack images. Then the regression analysis among soil crack characteristics, soil conductivity, soil soluble sodium and SOM is studied and the result is very satisfactory which means soil conductivity, soil soluble sodium and SOM of saline soil can be referred very well through this method with the soil crack parameters.**

***Key words*—saline-alkali soil, soil crack, soil conductivity, soluble sodium, SOM.**

INTRODUCTION

Soil salinization and second soil salinization are prevalent on a global scale, the total area of saline-alkali soil in the world is nearly 954 million ha [1]. The area of saline-alkali soil in China is approximately 34.6 million ha, of which only 7.6 million ha is used as arable land [2]. However, most of the saline-alkali soil area has a flat terrain and a thick soil layer which means the saline soil is quite potential for the tractor-ploughing. Effective improvement of saline-alkali soil, therefore, is very significant for both the yield and the ecological environment.

Soil crack is referred to as soil cracking caused by the contraction of dry-wet alternate soil particles. Generally, the soil crack is influenced by soil structure, soil chemical composition and soil moisture [3, 4, 5]. G. Musso points out that soil chemical composition especially soil salinity play a very important role in the process of soil cracking [6]. Particularly, the crack perimeter, the crack area and the crack texture features of one saline soil are all distinct from other saline soils because of their different soil salinities. Namely, studying the soil cracking condition can reflect the soil salinization degree and is also very significant for the saline-alkali soil improvement. Many researchers have focused on the extractions of soil crack perimeter and soil crack area, yet most results are disturbed by the artificial operations and therefore not satisfactory [7, 8, 9, 10, 11]. In this paper, the area and perimeter of soil cracks are detected by the surface roughness instrument in a non-contact, non-invasive online way base on the three-dimensional laser imaging technology [12]. In addition, several common GLCM (gray level co-occurrence matrix) texture feature measures of various soil crack images with different soil salinities are also calculated. After that, the correlations among soil crack characteristics, soil conductivity, soil soluble sodium and SOM (soil organic matter) are then studied.

STUDY AREA

Location

Songnen plain is one of the three soda saline soil distribution areas in the world and is also one of the main saline-alkali soil distribution areas in China. The total area of saline-alkali soil in Songnen plain is almost 3.42 million ha [13]. In this paper, western Jilin province (44.51503°~44.91188° N, 123.02007°~124.23404° E) is selected as the research region which is located in the south central Songnen plain.

Soil conductivity and salinity measurements

In this paper, six samples with various salinities from different places are selected in the research region. After that, the soil conductivity is measured by DDS-12D precision electric conductivity instrument and the content of soil soluble sodium is measured by FJA-2 computer control automatic titration system, the SOM and total salinity are also measured for each sample with results shown in Table I.

CONDUCTIVITY AND SALINITY MEASUREMENT RESULTS

Sample number	Soil Conductivity(ds/m)	Total Salinity(g/kg)	Soluble Sodium(mg/g)	SOM (g/kg)
1	1.91	8.91	26.40	3.63
2	1.99	5.41	30.70	6.33
3	1.17	5.91	13.70	6.90
4	0.77	6.23	9.80	4.21
5	2.29	5.15	33.20	22.05
6	0.64	2.16	7.40	7.86

Soil crack characteristic measurements

In this paper, the samples with different salinities are air-dried under natural conditions and then scanned by the surface roughness instrument in order to obtain the perimeters and the areas of soil cracks of different saline soil samples. Besides, the photographs of six samples are also processed for the GLCM texture features of different soil cracks. Specific measurement procedures are as follows.

a) Pulverize the six saline-alkali soil samples and stove them.

b) Get all the saline-alkali soil samples with the same quality, add water and stir the samples till their saturation conditions. Place the saturated samples into sample boxes with the same size respectively and rub them down, then put all the sample boxes in a ventilated place to dry the samples naturally. The crack images of six dried soil samples are shown in Figure.1.

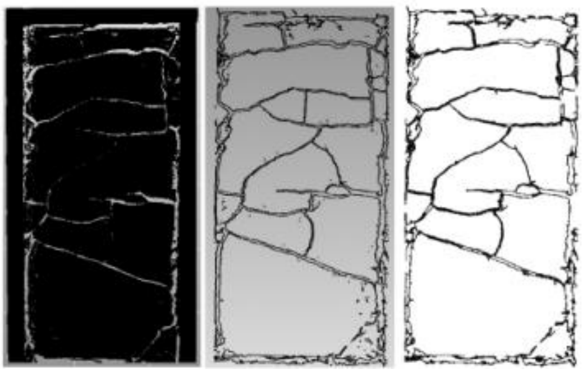
sample6 sample5 sample4 sample3 sample2 sample1

Figure.1. Dried soil samples

c) Take sample 1 as example for the soil crack characteristics, scan sample 1 by the surface roughness instrument to obtain its surface coordinate information, the result is shown in Figure.2a.

d) Go through all the points in Figure.2a and calculate the distance between each two pixels. After that, extract the edges of soil crack using appropriate threshold, the extraction result is shown in Figure.2b.

e) Connect the edge points in Figure.2b into a triangle and then calculate the total area of all the triangles with the surface model of Geomagic software to get the soil crack area with result shown in Figure.2c.



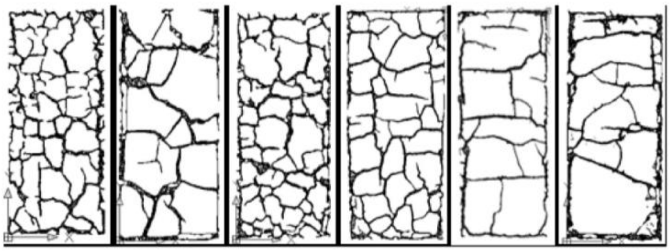
(a) (b) (c)

Figure.2. Processing results of sample 1 (a) Surface scanning result, (b) Edge extraction result, (c) Crack area extraction result.

f) Compute the edge points and the edge length of each crack using Otsu algorithm to obtain the soil crack perimeter.

g) Compute the GLCM of the soil crack photograph and derive the contrast, entropy, energy and homogeneity from the GLCM as the texture feature measures [14, 15]. We select gray level of 128, offset of 1 pixel，texture directions of 0°, 45°, 90° and 135° as GLCM parameters. Finally, the mean texture feature measures of four directions are used in order to avoid direction effects.

h) Repeat steps c to g for all soil crack characteristics of the six samples, the soil crack area extractions of six samples are shown in Figure.3 and the crack characteristic results are shown in table II.



sample6 sample5 sample4 sample3 sample2 sample1

Figure.3. Crack area extractions of six samples

REGRESSION ANALYSIS AND RESULTS

Establish the correlation analysis between the soil crack characteristics (area, perimeter and texture feature measures) of all the samples and soil conductivity, the correlation analysis between the soil crack characteristics and soil soluble sodium and the correlation analysis between the soil crack characteristics and SOM. The R-square values of linear fitting results are shown in table III, and the regression results are displayed in Figure.4, due to space restriction, only contrast is selected to be shown since its best fitting result to SOM.

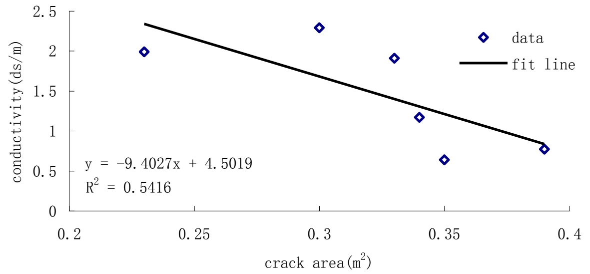
SOIL CRACK CHRACTERISTIC MEASUREMENT RESULTS

Sample number	Crack area (m^2)	Crack perimeter (m)	Contrast	Correlation	Energy	Homogeneity
1	0.33	7.96	37.088	0.935	0.00198	0.341
2	0.23	6.42	49.894	0.932	0.00143	0.263
3	0.34	9.15	49.091	0.946	0.00154	0.284
4	0.39	9.26	25.898	0.973	0.00195	0.351
5	0.30	6.07	72.964	0.932	0.00090	0.239
6	0.35	9.32	43.746	0.938	0.00194	0.330

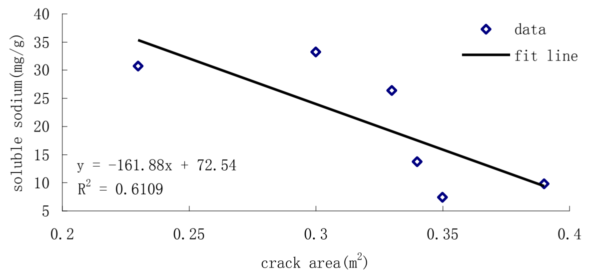
R-SQUARE VALUES OF FITTING RESULTS

parameters	Crack area	Crack perimeter	Contrast	Entropy	Energy	Homoge-neity
Conductivity	0.5416	0.8605	0.4170	0.4539	0.4619	0.4554
Soluble sodium	0.6109	0.9178	0.3919	0.4449	0.4543	0.4579
SOM	0.0658	0.3695	0.8068	0.7956	0.7487	0.544

It can be seen from table III that the R-square value between crack area and soil conductivity, the R-square value between crack area and soil soluble sodium are 0.5416 and 0.6109 respectively. To some extent, this means the crack area can infer soil conductivity and soil soluble sodium. The R-square value between crack perimeter and soil conductivity, the R-square value between crack perimeter and soil soluble sodium are 0.8605 and 0.9178 respectively. Namely the correlation between crack perimeter and soil conductivity and the correlation between crack perimeter and soil soluble sodium are both very significant. However, the correlation between SOM and crack perimeter, the correlation between SOM and crack area are neither significant. On the other hand, the correlations between SOM and GLCM texture feature measures are relatively high according to Table III although the texture feature measures are not remarkably related to both crack perimeter and crack area of saline soils.



(a)



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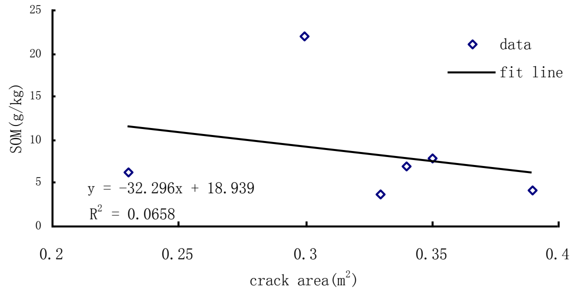
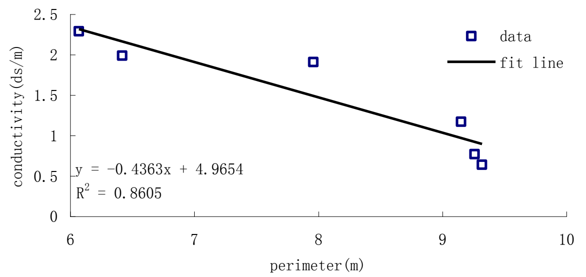
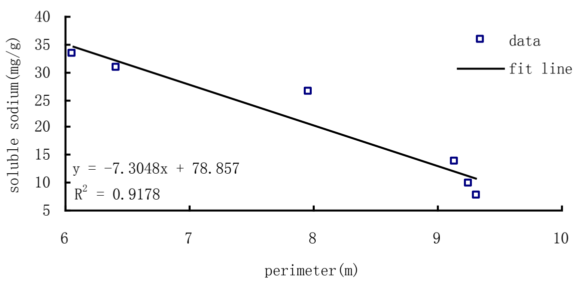


(c)



(d)



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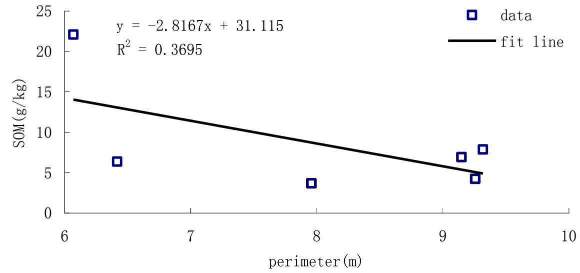

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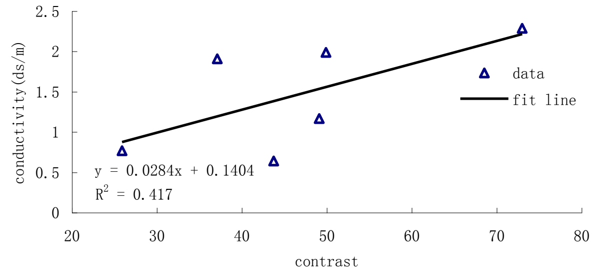
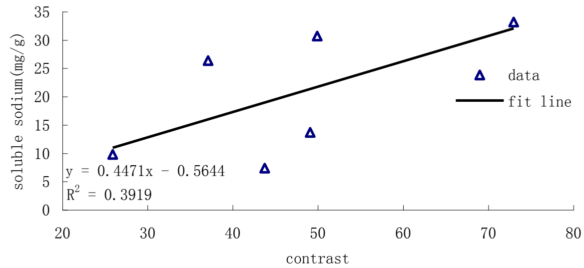
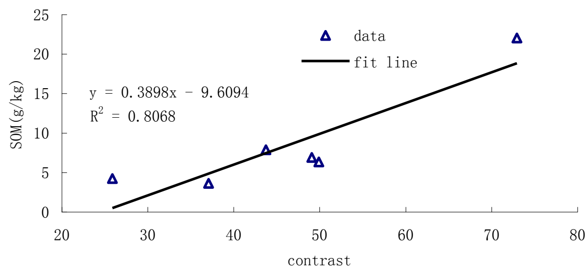


(g)



(h)



(i)

Figure.4. Linear regressions between crack characteristics and soil salinity parameters (a) linear regression between crack area and conductivity, (b) linear regression between crack area and soluble sodium, (c) linear regression between crack area and SOM, (d) linear regression between crack perimeter and conductivity, (e) linear regression between crack perimeter and soluble sodium, (f) linear regression between crack perimeter and SOM, (g) linear regression between contrast and conductivity, (h) linear regression between contrast and soluble sodium, (i) linear regression between contrast and SOM.

CONCLUSION

In this paper, the saline-alkali soils with different salinities are detected by the surface roughness instrument base on the three-dimensional laser imaging technology in a non-contact, non-invasive online way. The crack areas and crack perimeters of different soil samples are then extracted. Besides, texture feature measures of different saline-alkali soils are also derived from GlCMs of six soil sample images. The regression analysis are then performed among soil crack characteristics and soil salinity parameters and soil conductivity, the results of regression analysis show that the crack perimeter correlates significantly with both conductivity and soluble sodium and the correlations between GLCM texture features of soil crack and SOM are also relatively high. The soil salinities, therefore, can be referred through this method with different soil crack characteristics. However, only six soil samples are processed in this paper and the results may not very representative, besides, the cracking processes of different saline-alkali soils are also not discussed in this paper and this may be the following work we will focus on.

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