REMOTE SENSING ANALYSIS ON DYNAMIC CHANGES OF THE SOIL SALINIZATION IN THE UPPER STREAM OF THE TARIM RIVER

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ABSTRACT:

This research attempts to collect and interpret the soil salinization in the upper stream of the Tarim River on the basis of the multi-source and multi-type remote sensing images and basis background data in the springs of 1999, 2002 and 2004 respectively, applying the information technologies of remote sensing (RS), global positioning system (GPS), geographic information system (GIS), and massive data warehouse. The investigated data are collected, reclassified, stored and managed in a special warehouse built on the theory of the integrative spatial and attribute data, seamless integration of multi-source and multi-type data. They are analyzed both qualitatively and quantitatively in the framework of system classification, remote sensing interpretation, massive data built database and field investigations. The results show that the total area of salinized soil continues on growing in the research area, but the areas of bare lands and waters goes down one year after another, and the salinized soils close to the channels and the reservoirs improve more than that far away from any possible water sources, which scatter as small spots and vary irregularly in the land; The degrees of the saline-alkali soil in the target zone obviously become gradually weaker from the spring of 1999 to that of 2004 as a whole. The heavily salinized soil averagely decreases from about 6.89×10^5 hm^2 in area in the spring of 1999 to about 6.06×10^5 hm^2 in that of 2004 by 2.43% yearly; instead, the moderately salinized soil increases from about 2.20×10^5 hm^2 in area in the spring of 1999 to 4.23×10^5 hm^2 in that of 2004 by yearly 18.42% on average; while the mildly salinized soil frequently varies like waves between two extremes of cultivatable and salinized ones, with a far higher pace of improving than that of the worsening one; to sum up, the water treatment project plays a decisive and significant role in improving the salinized soil in this region, growing the area of none salinized soil, decreasing the area of heavily salinized soil and then promoting the ecological environment in the research region in this research.

1. INTRODUCTION

Soil salinization, one of the forms of resource degradation that causes difficulty for vegetation growth and engenders barren land because of excess amount of easily dissolved salts sequestered in the surface soil in arid and semi-arid region, badly affects the growth of vegetation, and reduces the utilization rate of land and crop production or leads to total destruction, which finally triggers great losses to human productions and ecological environment. In recent years, with the soaring population, declining arable land resources, the inconsistencies between the human beings and land resources have been rising greatly. By 2004, China's salinization land area had reached 1.74 x107hm^2, accounting for 27.46 percent of its total area, therefore monitoring, reclamation and treatment of land salinization have become the focus of current land use. The traditional ways of management for field survey, monitoring and soil condition analysis cost too much time and energy, and are poorly representative, which are unable to fully adapt to the demands of real-time, dynamic monitoring for large areas of land. The rapid development of information technologies such as RS and GIS, particularly remote sensing with the characteristics of widely covering, highly real-time, and truly reflecting the feature information of objects, which provides a new technical means for monitoring the dynamic change of soil salinization. Remote sensing monitoring by using multi-band and multi-temporal images data for saline soils and growing status of salt-tolerant plants has become hot researches and applications both at home and from abroad.

The Tarim River is the longest inland river in China, and the soil salinization is extremely severe in the upper stream of the Tarim River, which has become the major obstacle that restrains oasis ecological stability and social economic development. Many dynamic remote sensing analyses of saline soils have been conducted by scientists and institutions both at home and abroad, such as Tashpolat·Tiyip, who made a positive analysis of the soil salinization information extraction based on the remote sensing data in the arid inland Xinjiang Uygur Autonomous Region, Northwest of China in 2001; and the Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Science, who investigated the status and features of solinized soil in Liaohe River Delta, Liaoning Province, China, through remote sensing (RS) and geographic positioning systems (GPS) and other technologies in 2002. They have one in common, using the hi-tech remote sensing images and providing significant and scientific guidelines for the regional ecological environment dynamic monitoring and protection issues. However, most of them focus on the property analyses of soil salinazation and the growth of

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its areas, instead of integrative management of regional massive monitoring data and combination of qualitative and quantitative analyses together. The former are not convenient and sustainable for the basin ecological dynamic monitoring and administration of the corresponding massive data at a long term while the latter are essential and practical for the growing requirements of the regional long-ranged ecological monitoring. Based on the advanced technologies of RS, GIS, GPS, data warehouse and basic background information, we collect the multi-source and multi-temporal remote sensing images of the upper stream of the Tarim River Basin to interpret the local ecological environmental changes. The massive data are reclassified, stored in a special database, and treated by both qualitative and quantitative methods.The findings from the gathered data are then verified through the field investigations.This research aims to compare the dynamic changes of soil salinization in the upper stream of the Tarim River, and to provide the scientific basis for the region ecological environment construction, water resource allocation and integrated treatment of soil in the Tarim River Basin.

2. REGIONAL ENVIRONMENTAL BACKGROUND

The research area locates in the upper reaches of the Tarim River basin (81°30′～84°00′ E, 40°15′～41°30′ N), is typical of arid inland and desert climate in the warm temperate zone with rare rainfall and high evaporation, of which the averagely annual precipitation is around 20 to 50 mm and the annual evaporation amount reaches as much as 1800 to 2900 mm. Along both sides of the river, it consist of Quaternary alluvial fine sand and silt within the depth of 10m from surface, but the sandy soil occupies on the upper surface. Since the 1950s, with the increase of irrational human activities, soil salinization in the research area has been becoming a very serious problem, which forced some arable lands to be deserted and severely damaged the ecosystem and greatly threatened the agricultural production within the basin. This region has become one of the most serious regions with the problems of utilization of water resources and ecological environment among China's western arid areas, which have direct impact on China's western development strategy, therefore it is of great significance to choose the area for the study on rational development and utilization of salinized land resources in arid areas and prevention and treatment of secondary soil salinization.

3. STUDY BASIS

By field survey of the upper reaches of the Tarim River, we found that the research area showed strong salt return in spring, and the surface of saline soils formed smooth surface with salt crusting or salt skin, of which the spectral reflectance is much higher than that of other soils and is in great favor of information extraction for soil salinization, so the remote sensing data from three springs were collected as the basement data, combined with the basic geospatial data, the gathered data are reclassified and stored in a database for comparative analysis. All data are summarised into three parts:

(1) Remote sensing data. These include the full band image of TM on 23 February 1999, the full band image of ETM$^+$ on 26 February 2002, and the full band image of ASTER on 28 February 2004.
(2) Basic geospatial data. These are scaled at 1:100000 of digital line graphic and special map of the depth of groundwater, which are used as a total map for system control, geometric correction of remote sensing image, and background data for further query and display.
(3) Attribute data. These are composed of statistic data as population and social economy, and corresponding static attributes related to graphics.

4. STUDY METHOD

4.1 System classification categorizing of soil salinization

System classification is the basis of measuring ecological environment changes, and it is also the key to realizing dynamically monitoring the ecological environment through remote sensing. Combined with other relevant research results and the field survey, intensity classification method is applied in this paper in compliance with the relevant national standards such as National saline soil classification standard. In terms of the ratio of drifting salt occupying a unit area and the growing status of surface crops, the saline soils was categorised into four coverage types: none, mildly, moderately and heavily, to analyse the dynamic environmental changes in each period quantitatively in the research area.

Category of saline soils	Salinities of soils (%)	Classifications Index description
None	<0.2	Common crops can grow normally
Mildly	0.2～0.4	Cotton grows normally, but wheat is restricted, and the reduction of farmland crops is about 20% to 30%
Moderately	0.4～0.6	Growth of cotton is restricted, and the reduction of farmland crops is about 50% to 60%
Heavily	>0.6	Crops do not exist, but salt-tolerant pasture can survive, the reduction of farmland crops is more than 70% or 80%

Table 1. The classification system of types of saline soils

4.2 Multi-source remote sensing information interpreting

The remote sensing data come from two image sources, they are slightly different in characteristics of spectral bands and need to be processed respectively.

Firstly, the data of TM/ETM$^+$ images spectra bands 5, 4 and 3 are selected to make false colour composite, which reflects soil salinization better than others. The data on the ASTER satellite spectra band 4, band 3 and band 2 are included as well because the band characteristics are generally in accordance with those of TM/ETM$^+$ images. The images are then treated through geometric rectification and registration, image inlay, image enhancement and image cutting, and stored as the GeoTIFF format of remote sensing images with the latitude and longitude coordinate system at the scale of 1:100000.

Secondly, the information interpretation marks database is set up according to the determined category system of saline soils and the land features of images such as hues, shapes, shadow, texture and position.

Thirdly, the geographical conditions in the upper reaches of the Tarim River are relatively simple, and the salt contents of soils and image spectral information show good linear relationship. In the research, three period special maps of soil salinization at the scale of 1:100000 in 1999,2002 and 2004 with eligible precision, uniform classification and uniform spatial reference were completed by using the techniques that combine computer automatic extraction and visual interpretation, as well as basic geography, library of interpretation symbols, groundwater depth, salinity of groundwater, and through special information extraction as gradation & classification, *NDVI* index and supervised classification methods etc, as well as field survey and correction of the interpretation results based on GPS technology.

Finally, according to the data acquisition actuality and the future development requirements in the upper reaches of the Tarim River, the data warehouse management technology and spatial data engine (SDE) technology are adopted as the basis of the theory of the integrative spatial and attribute data, and seamless integration of multi-source data. Four databases such as basis database, RS database, special database and attribute database are built up and managed, and all data is achieved by corresponding procedures in this work.

5. ECOLOGICAL ENVIRONMENT CHANGE ANALYSIS

5.1 Soil salinization change

Different ranks of soil salinization interact with each other in reality. Their dynamic changes that we have obtained are in essence a rather perplexing process of interaction between natural forces and human activities. By comparing the changes of soil salinization within different periods, the research introduces the dynamic degree of land use to describe the different changing rate of saline soils within different periods in the research area. The formula is demonstrated as:

$$K = \frac{\mathrm{Ub} - \mathrm{Ua}}{\mathrm{Ua}} \times \frac{1}{\mathrm{T}} \times 100\%$$

in which *Ua* and *Ub* represents the initial and final land area of a certain land type respectively, T indicates the duration length of the study period, and k is the annual change rate of a certain land type in a period of time when the unit of T is given by the year. By statistics of the three period special data of saline soils, classified areas, change areas and dynamic changes information of saline soils in different periods are obtained (Table 2). The statistics data in Table 2 showthat the areas of different types of saline soils in the research area have changed greatly within the 5 years: (1) From 1999 to 2002, the areas of none and moderately salinized soil have increased, in contrast, that of mildly and heavily salinized soil display a decreasing tendency with years. (2) From 2002 to 2004, the salinity and alkalinity of soil in the target zone obviously become gradually weaker as a whole. The heavily salinized soil areas with more impact on human beings averagely decreases from 688046.27 hm^2 in 2002 to 605510.42 hm^2 in 2004; instead, the none, mildly, and moderately salinized soils areas show an increasing tendency from 38007.53 hm^2, 212310.41 hm^2, and 341069.81 hm^2 in 2002 to 38186.21 hm^2, 239388.39 hm^2, and 423131.23 hm^2 in 2004. (3) From 1999 to 2004, the areas of none salinized soil have a continually increasing tendency with an increase ratios of 0.37%; the mildly salinized soil frequently varies like waves between two extremes of cultivatable and salinized ones, with a far higher pace of improving than that of the worsening one; the areas of heavily salinized soil have decreased, with annual decreasing ratios of 2.43%; The total areas of salinized soils have increased from 1225918.67 hm^2 in 1999 to 1268030.03 hm^2 in 2004.

Salinized soil category	1999 Areas (hm^2)	2002 Areas (hm^2)	2004 Areas (hm^2)	1999-2004 Area changes (hm^2)	Salinized soil annual change(%)
None	37498.55	38007.53	38186.21	687.65	0.37
Mildly	316589.80	212310.41	239388.39	-77201.41	-4.88
Moderately	220254.08	341069.81	423131.23	202877.14	18.42
Heavily	689074.78	688046.27	605510.42	-83564.37	-2.43

Table 2 The acreage changes among soil salinization categories

5.2 Temporal and spatial variation tendency

Based on ArcGIS, two dynamic change maps of saline soils (Fig.1, Fig.2) were acquired by overlaying analysis of the three special maps in 1999,2002, and 2004. The dynamic change data of the special maps indicate that the spatial pattern had a great changes within the 5 years.

(1) From 1999 to 2002, the saline soils had a vast coverage area, but they mainly concentrated in Shayar, Kuqa and Xinhe counties, among which Shayar county had the most districts with transforming area of saline soils, followed by Kuqa county, and Xinhe county had the fewest with only small scattered patches of regions. The heavily salinized soil on the river side was slowing down, and the salinized soils close to the channel improved more than that far away from any possible water sources, which scattered as small spots and varies irregularly in the land.

(2) From 2002 to 2004, the water areas in the research area had decreased rapidly, instead, vegetation coverage areas had increased, and soil salinization had represented a relatively stable with narrower change range year by year, but the distribution locations changed, which mainly concentrated nearby waters in Kuqa county and Shayar county. Soil salinization close to water sources as Paman reservoir and the mainstream river region frequently varied like waves between two extremes of cultivatable and salinized ones, with a far higher pace of improving than that of the worsening one. Soil salinization in the regions far away from the river had altered within a smaller change range, which basically maintained their stability. the distribution status of soil salinization in the research area gradually improved, the vegetation coverage had increased, the ecological environment had tended to change for the better.

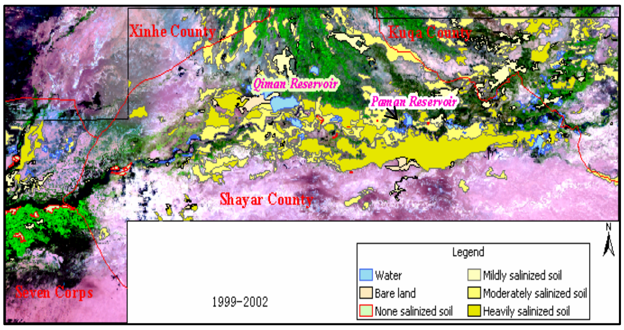

Figure 1 The overlay analysis map of salinized soil change and image in 1999 and 2002

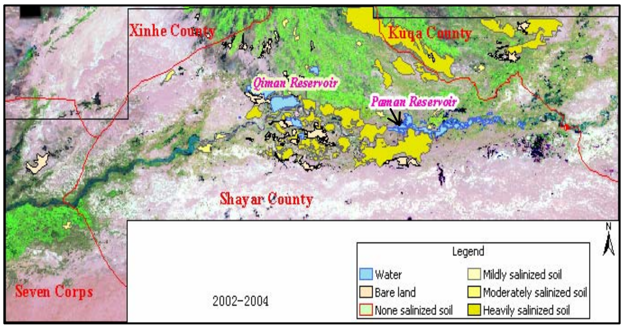

Figure 2 The overlay analysis map of salinized soil change and image in 2002 and 2004

5.3 Change Factors Analysis

Soil salinization, one of the forms of land degradation caused by the coaction of both fragile ecological environment and intensive human activities, can be influenced by many factors, but is mainly affected by natural and human factors.

(1) Natural factors: the research area is located in the center of Tarim Basin with flat terrain and gentle slope and poor drainage conditions, around which tertiary stratigraphy of salt bearing strata and gypsum-bearing strata are widely distributed. Most of the saliferous strata are exposed on the surface, thereby a large amount of salts have been accumulating in alluvial fan plains by means of surface runoffs or underground runoffs, so soil salinization have been increasing in some parts of the area. In addition, the climate with extreme drought and strong evaporation created conditions for the vertically upward movement of soil moisture and salt content. The salts dissolved in groundwater constantly move upward through capillary of soil with the evaporation of soil water, and eventually accumulate in the soil near the surface, salt has been generally accumulating in the basin soil, consequently, large areas of saline soil came into being in the Tarim River Basin.Clearly, the origin of soil salinization is the salt-containing parent materials, and the special climatic conditions are the major natural factors that cause soil salinization in the area.

(2) Human factors: human productive activities directly or indirectly affect the process of soil salinization. The irrigation of crops in the region mainly depends on overflow of surface water. From 1999 to 2002, soon after the implementation of the integrated treatment project, the research area was rich in water resource, and afterwards wasteland reclamation strengthened significantly, and some waste grassland and bare land were reclaimed into irrigable lands, therefore, the areas of none and wildly salinized soils had increased. Heavily salinized soil, however, after repeated eluviations and salt rinsed irrigation and large-scale cultivation and planting, salts of soil had been washed away around, so the salt distribution range changed and the area of moderately salinized soil increased greatly. From the ecological environment analysis, together with the field survey from 2002 to 2004, the variations of saline soils were mainly relevant to the local government's strict management, which reduced some improper irrigations such as flooding irrigation with excess quantity, and caused reversed changes of some types of saline soils, variations of distribution status of saline soils, increase of vegetation coverage, and improvement of the ecological environment by adopting trickle irrigation as well as reconstruction, excavation or cleaning of trenches and seepage-proof facilities.

6. DISCUSSION AND CONCLUSIONS

(1) A scientific and highly workable saline soil dynamic changes classification system was built up on the growing status of crops and the percentage of drifting salt per unit area in the research. The 3S hi-tech are set up in the analysis to interpret the remote sensing data. The results are verified and confirmed by field investigation and qualitative and quantitative analysis.This research shows that the research area’s total area of saline soils has been continuing to increase, but the salinization intensity has been dropping distinctly; soil deterioration and improvement coexisted, but the rate of melioration was faster than that of deterioration, the entire research area’s ecological environment has been getting better, the integrated treatment project has played a decisive role in improving the local ecological environment.

(2) Information technologies like RS, GIS, GPS and database were used to accomplish an overall, real-time, and dynamic method system of monitoring, analysis and application of soil salinization in this paper. This method possesses the advantages of less investment, shorter period, higher precision, and stronger maneuverability, and it is an important method and developing trend of continuous monitoring for ecological environment.

(3) Soil salinization monitoring is a long-term process, but this paper focuses only on the three periods of RS images and basic data, which are not up-to-date enough to tell us the true and whole story of the ecological environment in the entire region. With the development of spatial information, river basin information and software & hardware technologies, the dynamic changes of ecological environment will be reflected truly and objectively by supplementing and updating the river basin data and carrying through study and analysis with the support of geography analytical model.

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