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Effect of spatio-temporal change of land use on soil salinization in the Yellow River Delta

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ABSTRACT

Using remote sensing and GIS technology, through to the data of soil salinization and land-use and land-cover change (LUCC) in the four phases of the Yellow River Delta by retrieving and interpreting the four remote sensing images of 1984, 1995, 2005 and 2016, The paper analyzed the temporal and spatial variation of soil salinization degree and LUCC in the research area. The research presented a model of salinization detection index to monitor severity of salinization. The results showed that the correlation between the salinity index and soil salt content had a higher accuracy. Different land use types had a certain indication for the degree of soil salinization. The total trend of soil salinization degree of each land use types was cultivated land, grassland, construction land and mudflats from largest to smallest. Land reclamation and pasture degeneration are one of the main factors that aggravate the salinization and enlarge the area in recent years.

Keywords: Salinization; Land use; Yellow River Delta; Remote sensing

1. Introduction

Soil salinization often occurs in areas with arid climate, high groundwater level, high soil evaporation intensity and more soluble salts, and soil salinization often leads to the deterioration of ecological environment and the decrease of crop growth rate crop yield [1,2]. At present, serious soil salinization has become one of the main obstacles to the development of industry and agriculture in the Yellow River Delta. Therefore, obtaining real-time and reliable information on the properties, range, area, geographical distribution and degree of salinization of salinized soils is crucial to the management of salinized soils, preventing their further degradation and encouraging sustainable development of agriculture [3,4]. Remote sensing has become an effective means of detecting soil salinization with its macroscopic, comprehensive, practical, dynamic and rapid characteristics [5,6]. The coexistence of a variety of wetlands and concentrated contiguous river slides is a common landscape in the Yellow River Delta region, due to its special landscape caused serious degradation of vegetation, ecological fragility, the environment is very sensitive [7]. In recent years, human activities have become a factor that cannot be ignored in the development of estuarine delta [8]. Since the establishment of the Dongying City in 1983, the economic development in the Yellow River Delta has been accelerating. The land-use and land-cover change (LUCC) has rapidly accelerated under the influence of humankind. Changes in soil aggregates, changes in land-use and LUCC are one of the triggers [9]. Soil type, soil texture and soil type affect the transport of soil water and salt components in different ways, and soil water and salt transport together with other causes of soil salinization determine the degree of soil salinization [10]. So far, many domestic scholars have conducted detailed studies on soil salinization in the Yellow River Delta. However, most studies have done little research on the influence of natural

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factors on soil salinization and human factors. Changes in land-use and land-cover change directly reflect the dominant factor contributing to global change-human activity [11,12]. Human development and utilization of land and its resulting changes in land cover are considered to be an important part of the global environmental change and the main influencing factors [13,14]. Yellow River Delta tends to be diverse and complex [15,16]. The temporal and spatial variation of LUCC and salinization during the period was studied. With a view to provide some scientific basis for the prevention and control of soil salinization in the Yellow River Delta and land planning and management in Dongying.

2. Materials and methods

2.1. Research district's general situation

The Yellow River Delta is located between the west bank of Laizhou Bay and the south bank of Bohai Bay, between 36°55′ and 38°16′ N and 117°31′ and 119°18′ E, and is mainly distributed in Dongying City and Binzhou City in Shandong Province. The Yellow River Delta is a consortium of ancient, modern and modern four deltas. The research area is located within the scope of the modern Yellow River Delta. It is mainly bounded by the current coastline in 1855 and the ancient coastline, and the research area is about 2,719.8 km^2 (Fig. 1). The research area is the core area of the Yellow River Delta efficient eco-economic zone. The terrain is high in the southwest and low in the northeast. The elevation is 1–13 m and the natural ratio is 1/8,000–1/12,000. The research area belongs to the warm temperate semi-humid continental monsoon climate area, the annual average temperature is 11.7°C–12.6°C, the average rainfall is 540–660 $mm \cdot a^{-1}$, the summer rainfall accounts for 70% of the annual rainfall, and the average evapotranspiration is 770–2,390 mm. Saline soil is distributed throughout the research area. The buried depth of the dive site is about 1–2 m, the salinity is relatively high at 10–30 $g \cdot L^{-1}$, and the local area is more than 30 $g \cdot L^{-1}$. In the natural vegetation, the coastal salt vegetation, artificial vegetation in the main farmland vegetation. Yellow River Delta groundwater level is high, soil salinization is serious, most

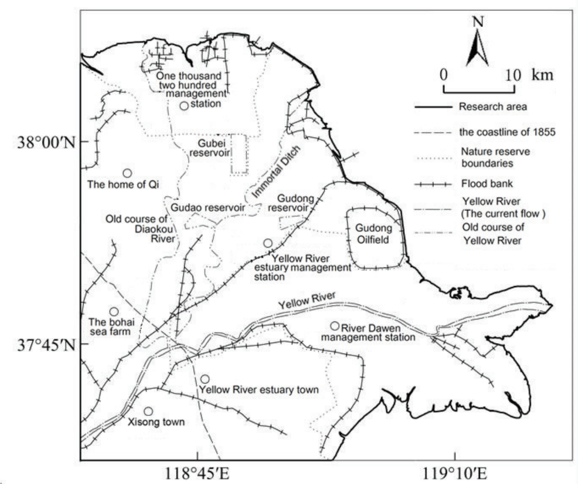

Fig. 1. Location map of research area.

are still wasteland, the coastline is gentle, rich in natural resources, is a piece of virgin land to be developed. Against the backdrop of the global environmental change and the prominent contradiction between people and land and the irrational use of land, the aggravation of soil salinization in the Yellow River Delta deserves our attention and research.

2.2. Research methods

2.2.1. Data source and preprocessing

In this paper, salinization and LUCC research were carried out in 1984 Landsat MSS image (resolution 80 m × 80 m) and Landsat TM image (resolution 30 m × 30 m) in 1995, 2005 and 2016. With the support of ENVI 4.6 and ArcGIS 9.2 software, the coordinate transformation and geometric precision correction of remote sensing images are carried out with reference to the 1:100,000 topographic map of the research area. At the same time, the 6S model correction parameters are used to deal with [16] atmospheric correction and surface reflectivity inversion and so on. The four phase data are based on Gauss-Kluge projection, the projection ellipsoid is Krasovsky, and the central meridian of the projection band is 117 00′ 00′ E. There is also the land planning map (1:100,000) and its vectorization data, vegetation data map and field measured data (including vegetation coverage, soil water content and soil salinity). Finally, the typical research area is intercepted. The coordinate range is 118°34′–119°15′ E, 37°36′–38°09′ N.

2.2.2. Method principle

The salinity index (SI) and normalized difference vegetation index (NDVI) were retrieved by radiometric calibration and geometric corrected Landsat MSS and Landsat TM reflectance data.

$$SI = \sqrt{\rho_1 \times \rho_3} \quad (1)$$

$$NDVI = \frac{\rho_4 - \rho_3}{\rho_4 + \rho_3} \quad (2)$$

where SI is salt index; NDVI is the normalized difference vegetation index; ρ_1, ρ_3, ρ_4 are Landsat TM data corresponding to reflectance values, Landsat data using MSS 2, 4 NDVI 1, 2 band inversion, the inversion of SI wave band.

Wang et al. [1] found that the remote sensing monitoring model of the salinized remote sensing monitoring index based on the relationship between NDVI, SI and soil salinization can be well reflected by the long-term study on Yutian oasis in the southern margin of Tarim Basin Soil salinization level, its expression is:

$$SDI = \sqrt{(NDVI - 1)^2 + SI^2} \quad (3)$$

where SDI is the salinized remote sensing monitoring index.

The SDI of 1984, 1995, 2005 and 2016 was retrieved by ENVI 4.6 software and then imported into ArcGIS 9.2

software to generate salt allelization of remote sensing monitoring index distribution (Fig. 3). The four remote sensing images were visually interpreted using ENVI 4.6 and ArcGIS 9.2 technology platform with 1:100,000 topographic maps, land planning maps and vegetation data maps of the research area (Fig. 4). Referring to the classification system of Chinese vegetation in 1980 and the land use dynamic remote sensing monitoring regulation of Ministry of Land and Resources, the research area is divided into seven categories: tidal flat, pasture, cultivated land, construction land, salt pond, shrimp pond and other water bodies (Table 1).

2.2.3. Model verification and analysis

The 38 sample points extracted in 2005 and 2016 were taken as the index values of soil salinization monitoring, and the correlation was analyzed with the total salinity of the soil surface, so as to verify the accuracy of the salinization index model of soil monitoring. The results showed that the correlation between soil salinization model and measured data was up to 0.794 and 0.832. The accuracy is higher than the correlation between the salt index and the measured data, which can reflect the salinization degree of the test area in the actual distribution of the land. This shows that the results of SDI model are reliable. Table 2 shows the average value of different types of salinized land salinization remote sensing detection index in 2005 and 2016, and the SDI difference between salinized land and non-salinized land is obvious. In 2005, the difference of SDI value between severe saline soil and non-salted land was the largest, reaching 0.436. The difference between the SDI value of the moderate saline soil and the non-salted land is 0.420, while the difference between the SDI value of the mild saline soil and the non-salted land is the least, but the result is still obvious, the difference value is 0.222. In 2016, the difference of SDI value between severe saline soil and non-salted land was the largest, reaching 0.462. The difference between the SDI value of the moderate saline soil and the non-salted land is 0.419, while the difference between the SDI value of the mild saline soil and the non-salted land is the least, but the result is still obvious, the difference value is 0.250. The results showed that the change of SDI could be used as an indicator for monitoring salinization.

Comparison of the SDI reflects the soil salinization level map and the total salt figure reflects the weight distribution of the field are consistent with salinization level quite high, indicating that the SDI value can reflect the level of soil salinization in the Yellow River Delta, as salinization monitoring indicators (Fig. 2).

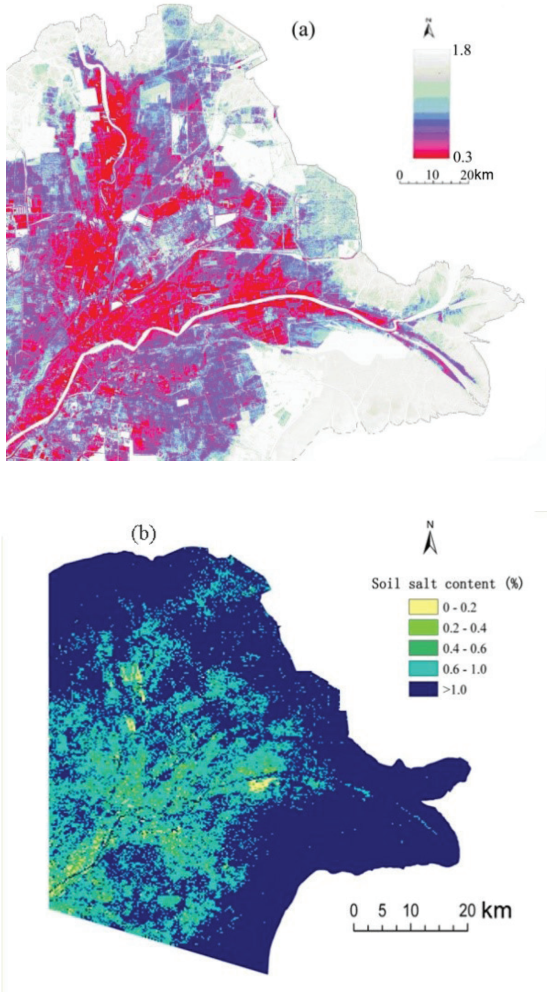

Fig. 2. (a) Soil salinization remote sensing monitoring exponential distribution map. (b) Yellow River Delta soil salinity distribution map.

3. Results and discussion

3.1. Soil salinization

The SDI distribution map contrast four periods can be obtained (Fig. 3). The most salinized areas are mostly distributed in coastal areas along the beach, the more salient the more inland salinization, after 1995, many were spotted or punctate. Moderate and severe salinization areas in the inland areas have been more obvious. In general, the degree of salinization of soils in the Yellow River Delta is increasing. The area and range of mild and moderate saline soils are becoming larger and the area and range of non-saline soils shrinking. Severe salts soil area and range of soil slightly increased. From 1984 to 1995, 10 years of slow economic development, the degree of regional salinization was not obvious, and most of the saline soil was non-saline and mild saline soil. From 1995 to 2016, in the two decades of rapid economic development, the degree of regional salinization has changed obviously. The proportion of saline and saline soil increased with the proportion of medium and severe saline soils and there was a clear trend of inland development. The current flow path of the Yellow River, the SDI value near the old course of the Yellow River and the reservoir is relatively low, forming strip distribution along the river and annular low salinization area distributed along the reservoir. The area and distribution of scattered salinization areas in the inland area have been continuously expanded to a point where the line from point to line in 2016. Thus, the level of soil salinization in the Yellow River Delta has reached a quite serious level, and it is necessary to analyze and reasonably explain the reasons behind the phenomenon of rapid salinization of soil [17].

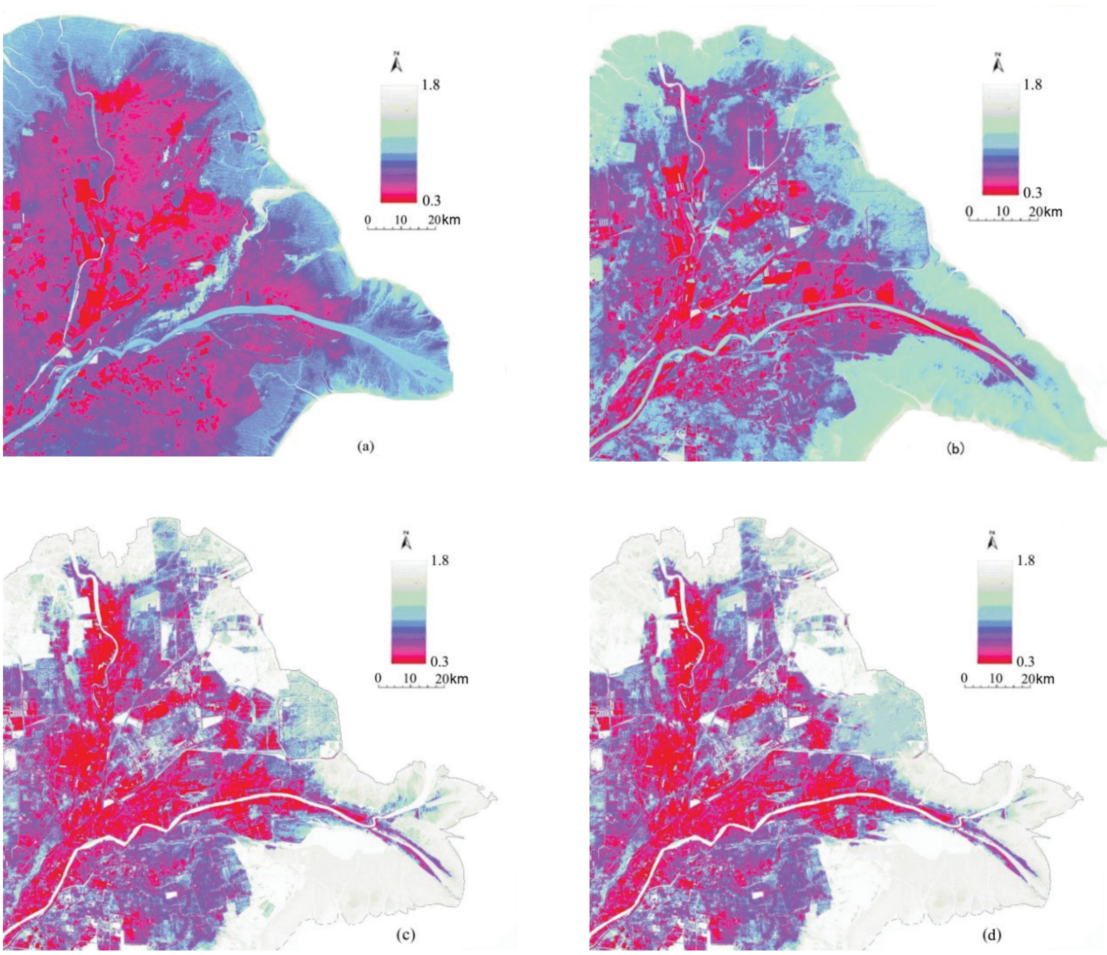

Fig. 3. Different period SDI distribution map ((a) 1984; (b) 1995; (c) 2005; (d) 2016).

Table 1
Classification scheme

Category	Meaning
Mudflats	A tidal zone between the high tide of a tidal wave and a low tide level, a tidal flat between the ordinary water level and the flood level of a river and a lake
Grassland	Woodlands of trees, shrubs, and other trees, and the land of animal husbandry and the land of reeds for growing herbaceous plants
Cultivated land	Land for planting crops, with a soil of about 1.5% salt in the surface soil
Construction land	Land, port and oil facilities for civil and industrial enterprises and enterprises in urban and rural areas
Prawn pond of salt pan	Shrimp, salt field
Water body	A river, a reservoir, and so on
Other lands	Refer to the basic no plant layer is about 10 cm thick plate, bare skin

3.2. Land-use and land-cover change

The accuracy of the LUCC maps obtained is tested by randomly selecting a number of sample regions and calculating their classification error matrices. The accuracy of the four phases is 83.05%, 86.28%, 87.32%, 88.54%. With the support of ArcGIS 9.2 software, the land use types of the four phases in the research area were superposed and analyzed, and the utilization area of various land use types in the four periods was obtained (Table 3).

Table 2
Value of remote sensing monitoring of salinization in 2005 and 2016

Degree of salinization	Severe	Moderate	Mild	Non-salty land
SDI of 2005	0.907	0.891	0.693	0.471
SDI of 2016	0.935	0.893	0.724	0.474

Comparing the land use and land cover change maps of the four periods, we can find that land use change is mainly manifested as arable land reclamation and pasture land degradation (Table 3). As a result of population growth, a large amount of land was cultivated. By 2016, the cultivated land area reached 1,246.83 km^2, and the reclaimed land area was about twice that of 1984. Coastal salt fields, shrimp ponds a substantial increase in area, in 2005 the area has grown to 270.95 km^2, about four times in 1984. Yantian and shrimp ponds are directly adjacent to arable land while the area is increasing. A large amount of pasture as a buffer zone disappears, forming a vicious cycle. As the core area of the Yellow River Delta efficient eco-economic zone, the Yellow River Delta National Nature Reserve occupies a large area, only a small number of small villages scattered among them without large urban areas, the corresponding increase in the construction area is small. Due to the increase of land for port and oil field facilities and the relatively small increase of urban and rural residential land use, the land area of 332.64 km^2 in 2005 is about 1.7 times of that in 1984. Degradation of pasture land is very noticeable, the area was reduced from 702.53 km^2 in 1984 to 354.60 km^2 in 2016. Owing to the massive encroachment of cultivated land and shrimp ponds, the area of natural forests and grasslands shrunk by about 62% in 2016. In addition, due to the selective construction of moisture dam in the northeastern Yellow River Delta, the area of beach area is reduced by about 20%.

All the land use types are the overall distribution trend from coastal to inland as follows: mudflats to prawn pond of salt pan to the grassland to cultivated land to construction land. (The expansion of arable land basically expanded along the current channel of the Yellow River and the old course of the Yellow River to the sea and to the highlands along the coast.) Some of the pastures along the river and the coastal area were reclaimed for cultivation. Some of them even swam with the tail of the Yellow River in some ecosystems of the new river beach cultivation. Cao et al. [18] found that the two phase movement of reclaimed pasture is an unreasonable "reclamation" and "nomadic" mode of production in the Yellow River Delta. The land use pattern presents a continuous cycle of reclamation, tillage, salinization, disposal and reclamation. This results in secondary salinization of a lot of land.

3.3. Land use on the impact of salinization

In order to deeply analyze the impact of land use on soil salinization in the research area, the four stages of salinization remote the SDI classification and visual

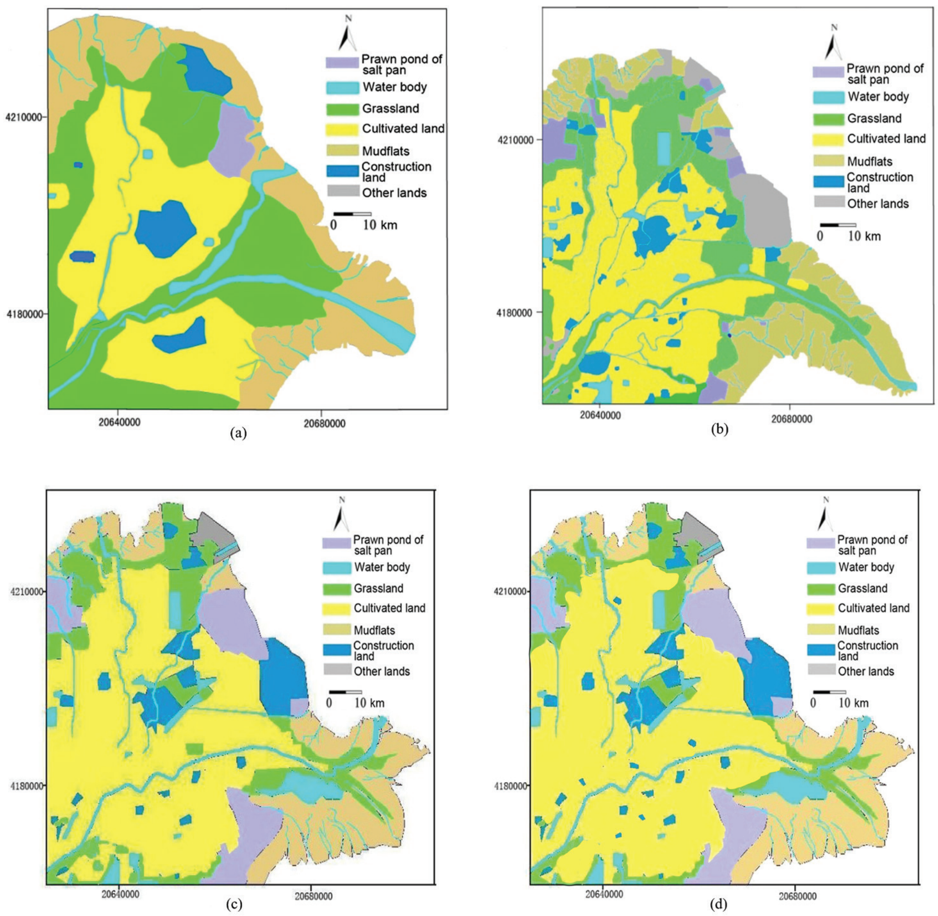

Fig. 4. Different period LUCC map ((a) 1984; (b) 1995; (c) 2005; (d) 2016).

Table 3
The change of area of land use

Type	1984	1995		2005		2016	
	Area/km^2	Area/km^2	Change in area accounts for 1984/%	Area/km^2	Change in area accounts for 1995/%	Area/km^2	Change in area accounts for 2005/%
Mudflats	650.64	467.06	–0.28	486.32	0.04	451.74	–0.07
Grassland	935.90	678.40	–0.28	459.31	–0.32	354.60	–0.23
Cultivated land	702.53	957.01	0.36	1,080.72	0.13	1,247.83	0.15
Construction land	195.31	279.63	0.43	332.64	0.19	384.64	0.16
Prawn pond of salt pan	65.42	146.51	1.24	270.95	0.85	201.05	–0.26
Water body (except rivers)	10.33	35.79	2.46	32.15	–0.10	34.57	0.08
Other lands		43.60		46.02	0.06	41.15	–0.11

interpretation of land use and land cover maps were overlay analyzed with the support of ArcGIS 9.2 software. The degree of salinization has a high correlation with various types of land use. Different types of land use have some indication to the degree of soil salinization, the total trend of soil salinization degree of each land use types was cultivated land, grassland, construction land and mudflats from largest to smallest. The distribution of arable land is mainly non-salinized soil and mild salinized soil. The distribution area of pasture is mainly mild salinization soil and moderate salinization soil. The distribution of construction land is mainly medium salinization soil. The distribution of tidal flat mainly is severe saline soil. Non-saline soil is widely distributed in the grassland and cultivated land area from 1984 to 2016, the distribution area is gradually shrinking, is compressed to the current watercourse of the Yellow River and cultivated land area of the Yellow River in both sides of the narrow. A lot of pasture for shrimp, shrimp, sea salt, salt makes the region by mild and moderate saline soil into severe saline soil, and increased soil salinization in surrounding area. The pasture land in local areas is often in the state of repeated sawing and sawing, which is dominated by salt and alkali land, sometimes salt and alkali, sometimes farming and sometimes grazing. The change in the distribution area of the construction land is more obvious, and the initial non-salinized soil and the mild saline soil mainly turn to moderate saline soil.

Land-use and land-cover change was originally a single, complex and disorderly from the original to the present. Due to the intensification of human activities, the already extremely fragile ecological pattern of the Yellow River Delta was broken, and the ability of nature to be repaired was reduced to a minimum. The distribution of various saline soils changed from the surface distribution in 1984 to the present patchy and dotted distribution, and even some moderate and severe salinization areas were planted in inland areas, and these areas were usually the most frequent area of human activity. About 80% of the arable land distributed in the most extensive area were non-saline soil in 1984, about 30% became mild saline soil by 1995, and about 60% will become a small part of mild saline soil and even moderate saline soil by 2005.

The construction of moisture-proof dam, port and oil field facilities in northeastern part of China will transform a part of beach land into pasture land so that the salinization degree of a considerable area in this area will be reduced from severe saline soil to moderately saline soil. The degree of salinization in the area of abandoned land in the reservoir area of southwest China has obviously decreased. This shows that reasonable land use can effectively prevent and cure salinization.

4. Conclusion

In this study, the characteristic space was constructed by using SI and normalized vegetation index. A remote sensing monitoring model for salinized land was established. The model was validated by using data of surface soil salinity measured in the field. The results show that the index value and the measured data have the same trend. The difference of land-use and land-cover change largely reflects the law of soil salinization degree. The total trend of soil salinization degree of each land use types was cultivated land, grassland, construction land and mudflats from largest to smallest. Moreover, the difference of land use and salinization degree showed the reverse change characteristics. The area with frequent human activities is the largest area of salinization degree change, which has accelerated the process of salinization to a large extent. Farmland reclamation and herbage land degradation, among the major factors, aggravate salinization and the expansion of the area in the study area in recent years. If we continue to let this unordered and uncontrolled land use way, the degree of salinization will be further deteriorated. Through the study of the impact of land use change on salinization, it will provide certain scientific basis for future research area to formulate reasonable land use planning to prevent and control salinization.

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