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Dynamic Development of Soil Salinization in Recent 40 Years in the Yellow River Delta

Feng Zhang*, Yuetong Xu

Geography and Environment College, Shandong Normal University, China
zfsrt@126.com

Based on four periods of remote sensing images, the analysis of the development of soil salinization in the Yellow River Delta in recent 40 years was carried on by the soil salinization change dynamic degree which is deserved from dynamic degree analysis method in three stages and by the development intensity of soil salinization which is deserved from the transformation matrix.

1. Introduction

The Yellow River Delta (YRD) is located in Northeastern Shandong Province, is new land deposited by the Yellow River in the Bohai Bay in nearly a hundred years, is adjacent to the Bohai Sea in the east and north, and is one of China's three major river deltas. The research object is the modern YRD in 118.184°~119.306°E, 37.322°N~38.142°N. More than 96% of the area distributes in Dongying City, Shandong Province, a small part in Zhanhua County, Binzhou City and the area is more than 5000 square kilometers.

2. Data sources and research methods

2.1 Data sources

The time span of this research is about 40 years, and the data used include:
(1) Four phases Landsat satellite remote sensing data in 1976, 1992, 2003, 2015 obtained from the USGS;
(2) Years of research results and data accumulated by research group;
(3) Field sampling data, mainly including the field soil sampling data in 2003, groundwater sampling data in 2003. These data was experimented and analyzed in the field or laboratory.

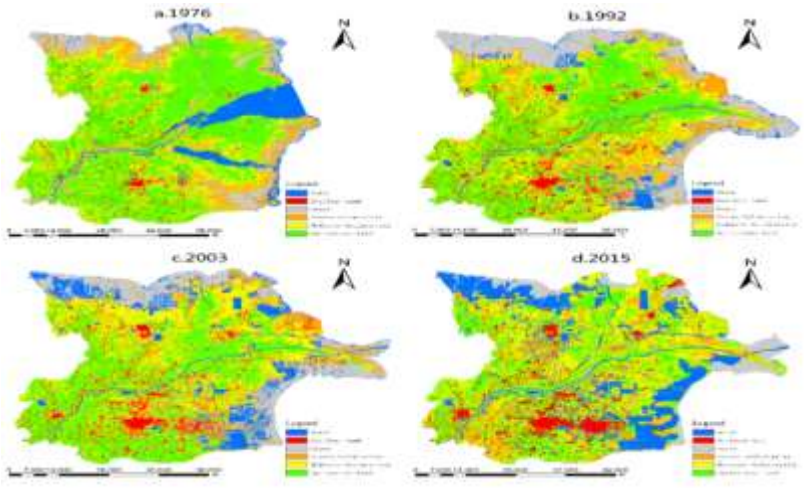

Figure 1: Soil salinization classification map of the YRD in 40 years

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2.2 Remote sensing image classification

According to the classification scheme, the classification of soil salinization in the study area is as Fig.1.

2.3 The model of salinization dynamic degree

Single dynamic degree is used to measure the change range of salinization various types. Single landscape type dynamic degree can be used to describe the change number of variety of landscape types in the study period. When the results is positive numbers, it shows that landscape types are in an increasing trend and when the results is negative numbers, it shows that the landscape types in the study period are in a decreasing trend. Formula is established about single dynamic degree model of salinization:

$$K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \cdot$$

In the Formula: K is salinization dynamic degree in the study period. When $K > 0$, soil salinization area is in a decreasing trend; when $K < 0$, soil salinization area is in a increasing trend; U_a, U_b respectively is the area of salinization of the beginning and end of the study area; T is the length of the time period, and in this study each time is decided according to the time between two RS images.

2.4 Salinization change intensity

The salinization types transfer matrix of the adjacent period is constructed to reveal the direction and quantity of the different periods. Meanwhile, spatial transfer matrix analysis method is used to divide the study area into 4 categories: beach, severe salinization, moderate salinization, and agricultural land, and the categories are respectively given 1, 2, 3, and 4 value. ArcGIS is used to carry on data transfer spatial discriminant analysis of salinization types, and then to combine and classify the analysis results. Finally the study area is divided into five grade: intense improved, improved, stability, degradation, and intense deterioration.

Table 1: The classification of salinization types transformation in the study area

Classification type	intense deterioration	deteriorati on	stabilizati on	improv ed	intense improved
Classification	≥2	1	0	-1	≤-2
transfer matrix	4→2	4→3	2→2	1→2	1→3
	4→1	3→2	3→3	2→3	1→4
	3→1	2→1	4→4	3→4	2→4

According to the transfer matrix of saline soil, the intensity of the development of salinization in the YRD is obtained in Fig. 2.

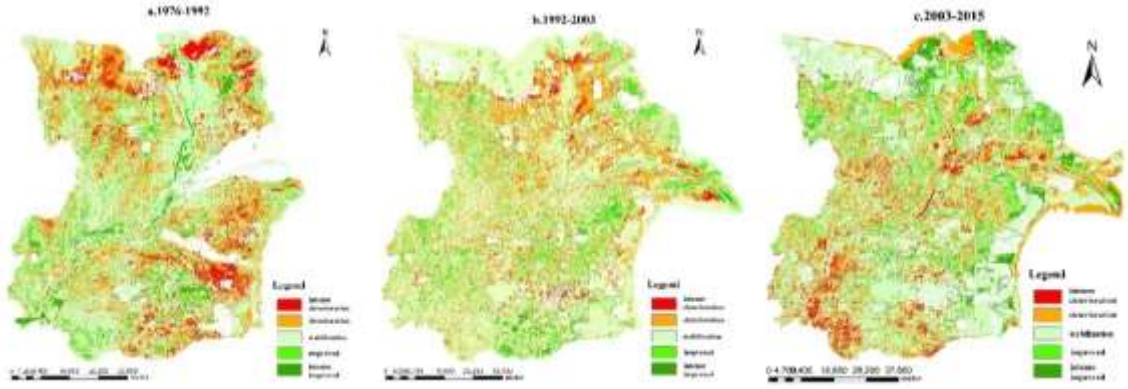

Figure 2: Intensity of the development of salinization in the YRD in recent 40 years

3. Results and analysis

3.1 Years development of soil salinization in the Yellow River delta 40 years

According to the four stages of the YRD soil salinization classification map, in recent 40 years, the distribution of soil salinization in the YRD has changed greatly, and this mainly shows two characteristics:

(1) Soil salinization began to spread from the original soil salinization area to around, on the one hand from coast to inland, on the other hand from the original "northwest-southeast" line to the northeast, southwest, and the salinization degree of the original area aggravated.

(2) The fragmentation of soil salinization aggravated and the distribution area become more and more extensive. Especially in recent ten years, the distribution of soil salinization is no longer near the original "northwest-southeast" line, but more widely in all the YRD. In the "northeast-southwest" region, some severe salinity distribution concentrated area appears.

The superposition of the YRD soil salinization distribution map and the topography map can arrive at some conclusions: the hillock-terrace is the geomorphic types of the lightest soil salinization, and the highland formed by river and the flat ground take second place; flood land and shallow-flat-depressions soil salinization is heavier. It can be seen from the YRD land use type map overlaid with 2015 soil salinization distribution map, in addition to the coastal areas, higher soil salinization area mainly distributed in irrigated fields, irrigation ditches intensive area, and southeastern regional coastal brine mining area.

According to the classification of remote sensing image in the 4 phases of the YRD, the statistical classification table 2 is obtained, and then according to the table, the soil salinization of each type of the soil salinization in 40 years is plotted like Fig. 3. From table 2, dynamic degree analysis can be used to get table 3 and Fig. 4.

Table 2: Classification results of the study area in the YRD (HA)

	1976	1992	2003	2015
Water	75204.09	40994.37	75977.55	121437.9
Resident land	8022.15	30659.85	40146.21	47598.93
Beach	61439.49	116252.28	94681.17	42306.12
Severe salinization	81282.33	90068.94	82843.56	58776.66
Moderate salinization	117478.44	156710.61	171904.41	176718.96
Vegetable land	288409.86	225895.59	187679.52	188480.52

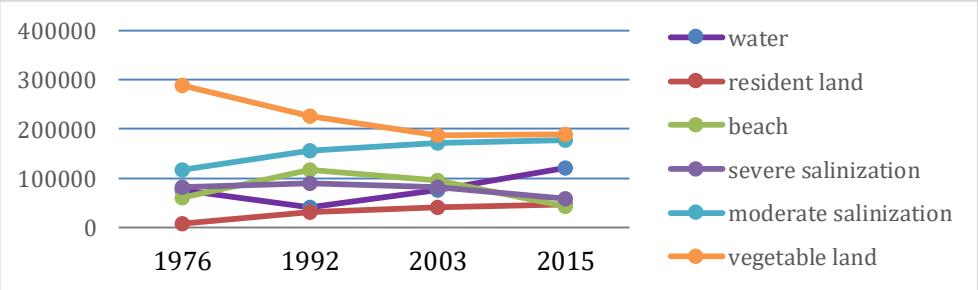

Figure 3: Line chart of the development of soil salinization in the YRD in 40 years

Some information can be got from table 2, table 3 and Fig. 3, Fig. 4. In recent 40 years, the YRD water area has been in a growing state in addition to the 1992 at a low. But in the remote sensing images of 1976 the water of the Yellow River occupied the most, and the estuary is very wide. Removing this factor actually the YRD water area in recent 40 years has been in a growing state. Dynamic degree of residents has been positive, but the value has been reduced. It shows that the residential area has been increased, but the increase is reducing. The area of severe salinization region from 1976 to 1992 is in the growth state. But after 1992 the area has been reduced with an average annual decrease of 1366 ha. Moderate salinization area has been in a state of growth, but the growth rate has slowed down in nearly ten years. The agricultural land area has been reduced at first, but now is in a state of increased with a small magnitude. Beach area from 1976 to 1992 is being growing greatly, but later it continues to reduce, and the reducing magnitude is also increasing.

Table 3: Analysis of soil salinization dynamic degree in the YRD (HA)

Classification	1976-1992	1992-2003	2003-2015
Water	-2.84	7.76	4.99
Resident land	17.64	2.81	1.55
Beach	5.58	-1.69	-4.61
Severe salinization	0.68	-0.73	-2.42
Moderate salinization	2.09	0.88	0.23
Vegetable land	-1.35	-1.54	0.04

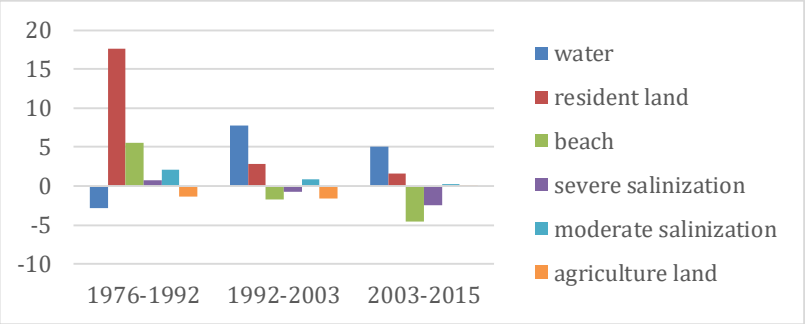

Figure 4: Chart of the YRD soil salinization dynamic degree change in recent 40 years

3.2 Study on the changes of soil salinity in the study area

Table 4: Soil salinity development intensity in the YRD (HA)

Year	Intense deterioration	deterioration	stabilization	improved	Intense improved
1976-1992	19177.2	49430.43	250757.28	132522.66	45384.3
1992-2003	13035.42	77434.56	327879.36	110375.91	19905.93
2003-2015	34161.84	123856.6	269151.1	71182.71	36485.1

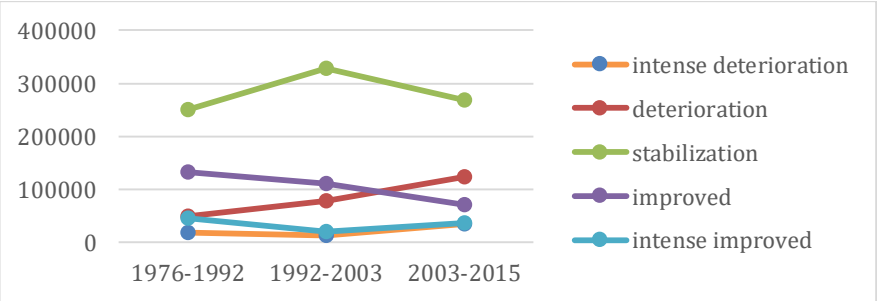

Figure 5: Line chart of the development intensity of soil salinization in the YRD in recent 40 years

According to the transfer matrix of Table 3, the intensity map of salinization development was drawn, and the causes of the level of the transfer of various types of salinization are analyzed.

In the three stage, land types in stable state have the largest area, first increasing and then reducing with a narrow range. The area of the improved has been reduced, and in recent years the reducing amplitude is in the increasing trend. The deterioration area has been increasing, and the range of the increase in recent years has increased. The deterioration area has exceeded the area of improved land. The strong deterioration and the strong improvement land types first reduced then increase, and in 2015 only a little difference 2324 ha. But the area of greatly improved land has been larger than that of greatly deteriorated land. Although from the first stage to the second stage of the process, the decline magnitude of the intense improved land is greater than that of the intense deteriorated land, but the area of the deteriorated and the intense deteriorated of the area

are larger than that of the improved and the intense improved land. From the above analysis, it can be concluded that the soil salinization in the YRD is in a relatively stable state, but the salinization level has been increasing.

From the spatial distribution, in the first stage the strongly deteriorated region mainly distributed in the YRD's north coastal regions and the southeastern, and is the serious salinization area around 1992. In the second stage, the strongly deteriorated region distributed in coastal areas of the northeast YRD. From the northeastern coastal areas to the southwest inland the regional distribution is: intense deteriorated, deteriorated, improved. The strong improved distribute more in the southeast of the YRD. Relatively large changes happened in the third stage: the strongly deteriorated mainly distributed in the southwest and north of the Yellow River, and the strongly improved distribute near the coast area more.

4. Cause of formation

The YRD is located in the coastal area where mainly the Bohai saline alkali soil distributes in and the soil salinization process is before the process of soil forming, and gradually developed into land on the basis of the salt mud. Precipitation and evaporation, topography, soil texture, groundwater salinity, water supply and drainage, and human activity intensity are the leading factors in the formation and evolution of soil salinization.

The YRD is a warm temperate monsoon climate, with obvious dry and wet alternation, precipitation concentration and other characteristics. All these situations easily lead to the seasonal soil salt accumulation and desalination. Groundwater depth is shallow in the YRD; groundwater recharge is mainly depended on precipitation, and groundwater discharge is mainly depended on evaporation and plant transpiration. The precipitation in the YRD is between 530-635 mm, and the evaporation intensity is very high in 1900-2400 mm, and the rate between evaporation and precipitation is more than 3.6:1.

The study area is the coastal delta physiognomy deposited by the Yellow River alluvial deposit in the Bohai Sea, and is a modern sediment in shallow sea. It's formed by sediment carried by the Yellow River, affected collectively by the backwater and maceration of the seawater, tides and waves, and some other factors, and controlled by seawater immersion. In the alluvial plain, mild slope is most likely to accumulate salt and its salinization degree is the highest; Highlands formed by river and depressions only have vertical movement of water and salt in general. The soil texture that of the former is partial sand and the latter partial glue is not conducive to long distance or fast delivery of water and salt. But if the underground water level once is beyond the critical level, moisture evaporation loss will continue to be supplied by underground water, and salt will continuously accumulate on the surface.

The east of the study area is effected by seawater immersion and lateral penetration intensely, and the mineralization degree of groundwater is relatively high. These parts are influenced more strongly by groundwater salt return, and this results in that surface soil salt accumulation is higher than the other parts. And in recent years the situation that rainfall in coastal regions is reducing frequently and rivers are drying up makes the water intrude into the aquifer along the river or by the underground, and further exacerbate the degree of salinization in the coastal areas. In addition, the coastal areas are also vulnerable to the impact of regular storm, and this is another important reason for the accumulation of salt in the coastal areas.

The Yellow River irrigation breaks the regional balance of water and salt and raises the groundwater level. The irrigation project wastes water seriously due to the imperfect supporting facilities and the lack of management experience of large-scale irrigation area; extensive agricultural practices lead to soil secondary salinization seriously in the western irrigation area. The fragmentation of soil salinization distribution also indicates that the influence of human to soil salinization is becoming more and more.

5. Conclusions

In recent 40 years, the development and changes of soil salinization in the YRD is closely related to the natural factors, such as the local climate, topography, and geomorphology, and other man-made factors. On the one hand, the distribution area of soil salinity is increasing, and the distribution is more and more fragmented. The distribution concentration region gradually developed from the coastal areas and near the "northwest-southeast" line originally to the whole YRD; severe salinization concentrated changed from the coastal areas to the inland region; intense deterioration areas distribution also developed from coastal area accounted for advantage to inland accounted for advantage, and the area is expanding. On the other hand, through human some improvement measures, part of salinized soil gradually improved. The severe salinization area is gradually reduced, the strong improvement area assumes the trend of escalation.

According to the change law of the soil salinization in the YRD in recent 40 years, governance practice can take the following measures: using policy, system and method as guidance and coordination to the disorder of irrigation agriculture to strengthen the drainage management, and to reduce groundwater unreasonable source; using the engineering measures, such as dark pipe changing alkali and building platform fields, for salt drainage, storing freshwater, suppressing alkali, and reducing the underground water level to below the

threshold to control the source of salt; using advanced agricultural technology and biological measures to reduce soil evaporation; introducing planting salt-tolerant plants and grass to carry on greening work to reduce the exposed surface and slow the increase of capillary water in the soil; regulating and guiding environmental brine and aquaculture production activities to reduce the infiltration of high salinity water; strengthening groundwater monitoring, controlling the underground water exploitation, constructing related projects in the coast to prevent seawater intrusion and avoid groundwater salinity increasing.

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