The study on dynamic characteristics of soil erosion in Yuyao City of Zhejiang Province

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Abstract: Taking Yuyao city as the study area, using GIS technology to establish a database of soil erosion. Based on the database, soil erosion in the study area was evaluated and the dynamic variation of soil erosion intensity was analyzed. The results showed that during the past ten years from 2004-2014, the overall situation of soil erosion in Yuyao city had improved, and the total area of soil erosion decreased year by year, with an average annual reduction rate of 3.3199 km\textsuperscript{2}/a. But high intensity erosion area increased due to mining, quarrying, road building caused by. And some area had the evil trend, however the area was not large. In the process of the dynamic transition of erosion, the weakening area of erosion mainly came from the transition of slightly eroded area to non-apparently eroded area. the exacerbating erosion area mainly came from the transition of non-apparently eroded area to the slightly and moderately eroded area.

1 Introduction
Soil erosion not only resulted in the destruction of land resources, caused the decline of land productivity, but also brought about the ditch pond siltation, thereby reducing the drainage ability, led to the decline of agricultural productivity [1, 2]. These serious threatened to the survival and development of human beings, had become a hot issue of universal concern [3, 4, 5]. The study of dynamic evolution, distribution, prediction and control countermeasures of soil erosion had become an important part of the global change research, and also had become the common concern issue of Century International Soil Science, agriculture and the environment science [6]. At present, the study of soil erosion dynamics using erosion model had become a hot spot in the world, and it also had become a powerful tool for the study of soil erosion dynamics [7]. Qi et al. [8] analyzed the dynamic change characteristics of soil erosion in Fushun city. Xi et al. (2016) studied the distribution characteristics of soil erosion in the Loess Plateau. Li et al. [10] discussed the characteristics of soil erosion the in Yan-he River watershed using GIS and remote sensing technology. The soil erosion in Abide Mountain Area was predicted by using the USLE equation [11]. Zhao et al. [11] carried out the study of spatial distribution and prediction of soil erosion in Anhui province.

In China, a lot of studies had been carried out on the quantitative prediction of soil erosion, but the environment factors were very complex in the southeast coastal area of China. The study of soil erosion in these areas was weak. Therefore, this paper chose Yuyao city as the study object, and the characteristics of soil erosion quantitatively were analyzed in the study area, which provides the basic data for the comprehensive management of soil erosion and ecological environment construction in Yuyao city.
2 Data and Methods

The study was based on soil erosion remote sensing investigation data of Yuyao city. Using of GIS superposition calculation function, soil erosion maps of different periods were overlaid, and the attribute table value were further processing and analysis to obtained dynamic change data of the soil erosion. Based on the statistical analysis method of GIS, the soil erosion data of three stages in 2004, 2009 and 2014 were established. According the People’s Republic of China Water Conservancy Industry Standard, Standards for Classification and Gradation of Soil Erosion (SL190-2007), the intensity of soil erosion was divided into 6 grades which were non-apparently eroded, slightly eroded, moderately eroded, severely eroded, very severely eroded and extremely eroded. On this basis, this paper analyzed the variation characteristics of soil erosion in Yuyao city from 2004 to 2014.

3 Results and Analysis

3.1 The variation trend of soil erosion area

According to the data of three soil erosion remote sensing surveys of Zhejiang province, soil erosion data of different intensities was arranged in table 1. Since 2004, the total soil erosion area in Yuyao city had been gradually reduced. From 2004 to 2009, the total soil erosion area had been reduced by 17.4%, and the average reduction rate was 6.1912km²/a. From 2009 to 2014, the total soil erosion area was reduced by 1.5%, and the reduction rate of soil erosion area was 0.4485km²/a. Compared to the first five years (2004-2009), soil erosion area reduction rate of the latter five years (2009-2014) decreased obviously, reduction rate of the first five years was 12.8 times more than that of the latter five years. From 2004 to 2014, the total soil erosion area decreased by 18.6%, with an average annual reduction rate of 3.3199km²/a. It can be seen that the first five years was the most prominent period of soil erosion area reduction in Yuyao city.

| Gradation of soil erosion | 2004   | 2009   | 2014   |
|--------------------------|--------|--------|--------|
| 1                        | 1120.8579 | 1151.8139 | 1154.0565 |
| 2                        | 143.1348  | 55.9515  | 58.3250  |
| 3                        | 32.1876   | 67.9765  | 68.4970  |
| 4                        | 2.3118    | 17.1705  | 12.7714  |
| 5                        | 0.5858    | 5.5644   | 4.8247   |
| 6                        | 0.0744    | 0.6755   | 0.6777   |
| Erosion                  | 178.2944  | 147.3384 | 145.0950 |

Note: in the table 1– non-apparently eroded, 2– slightly eroded, 3– moderately eroded, 4– severely eroded, 5– very severely eroded, 6– extremely eroded. Erosion – sum of 2 to 6. The unit is km². The following tables were the same.

From the area variation of different erosion intensity, slightly eroded area reduced 87.1833km² from 2004 to 2009, while the area of other erosion intensities increased, the increase amplitude was 35.7889km² (moderately eroded), 14.8587km² (severely eroded), 4.9786km² (very severely eroded), and 0.6011km² (extremely eroded). Hence one can see that reduction of the total soil erosion area in the first five years was mainly due to the reduction of the slightly eroded area. From 2009 to 2014, severely and very severely eroded area were reduced by 4.3991km² and 0.7397km². However, slightly, moderately and extremely eroded area were increased by 2.3735km², 0.5205km² and 0.0022km². So, in the latter five years, the area of high intensity erosion decreased slightly, and the area of low erosion intensity increased slightly. From 2004 to 2014, the variation law of soil erosion area was similar with the variation in 2004-2009. It performance as that the slightly eroded area decreased, the eroded area of other gradations increased. Over the past ten years, the slightly eroded area had been reduced by 84.8098km², and the erosion area of other gradations increased by 36.3094km² (moderately eroded),10.4596km² (severely eroded), 4.2389km² (very severely eroded) and 0.6033km² (extremely eroded), respectively.
3.2 The variation characteristics from 2004-2009
Table 2 showed the transition results of different erosion intensity area from 2004 to 2009. In the total area of 1299.1523km², the area which of erosion intensity did not change was 1034.2833km², and the area of erosion intensity change was 264.8690km². Among them, the erosion weakening area was 138.3715km², the erosion exacerbating area was 126.4975km². The erosion exacerbating area mainly came from the transition of the non-apparently eroded area in 2004, which accounted for 83.2% of erosion exacerbating area. This area was mainly transited to slightly eroded and moderately eroded area. slightly eroded area mainly transited to moderately eroded area, which accounted for 11.5% of erosion exacerbating area. The transition area of moderately, severely and very severely eroded totally accounted for 5.3%. In the erosion weakening area, the transition area from slightly eroded area in 2004 to non-apparently eroded area in 2009 were very obvious. the slightly eroded transition area accounted for 25.8% of the erosion weakening area. Moderately eroded transition area accounted for 18.9%, which mainly transited to non-apparently eroded area, this transition part accounted for 49.0% of the moderately eroded transition area. The transition area of severely, very severely and extremely eroded, totally accounted for 1.6%. The weakening area was mainly transited into non-apparently eroded area.

3.3 The variation characteristics from 2009-2014
The statistical results of the transition area of different erosion intensity were counted in table 3. The same can be seen in this 5 years (2009-2014), the area of erosion intensity unchanged was 1250.2438km². And the area of erosion intensity changed was 48.9085km². Among them, the erosion weakening area was 22.1669km², accounting for 45.3%, the erosion exacerbating area was 26.7416km², accounting for 54.7%. The erosion exacerbating area mainly came from the transition of non-apparently eroded area in 2009. this part area accounted for 85.3% of the erosion exacerbating area. and the non-apparently eroded area mostly transited into slightly eroded and moderately eroded area. the erosion exacerbating area of slightly eroded area accounted for 8.7% of erosion exacerbating area, which was mainly transited into moderately eroded area. the erosion exacerbating area of moderately, severely and very severely eroded totally accounted for 6%. From the analysis of erosion weakening. the erosion weakening area came from slightly eroded area in 2009 into non-apparently eroded area in 2014 accounted for 25% of the erosion weakening area. erosion weakening area from Moderately eroded area of 2009 into slightly eroded area of 2014 accounted for 39.4% of the erosion weakening area. which mainly transition into non-apparently eroded area, and accounted for 81.8% of the Moderately eroded weakening area. also, the erosion weakening area came from the transition of severely eroded area accounted for 25.8% of the erosion weakening area, which mainly transition to non-apparently eroded area, and it accounted for 65.5% of severely eroded weakening area. the erosion weakening area of very severely and extremely eroded area totally accounted for 9.8%.

3.4 The variation characteristics from 2004-2014
The table 4 provided the statistical results of the transition area from 2004 to 2014. It can be concluded from it that in the ten years, the area was 1039.3798km², where the soil erosion intensity did not change. And the area was 259.7725km², where the soil erosion intensity changed. Among the changed area, the erosion weakening area was 137.0352km², and the erosion exacerbating area was 122.7373km². The erosion exacerbating area mainly came from the transition of non-apparently eroded area in 2004, this part area accounted for 82.9% of the erosion exacerbating area, which was mainly transited to slightly and moderately eroded area. the slightly eroded exacerbating area accounted for 16.1% of the erosion exacerbating area, and of which 77.6% was transited to moderately eroded area. The moderately eroded exacerbating area accounted for 0.8% of the erosion exacerbating area, of which 61.6% was transited into severely eroded area. the erosion exacerbating area came from severely and very severely eroded area only accounted for 0.2%. Based on the statistical analysis of erosion weakening area, the results showed the non-apparently eroded area, which transited from slightly eroded area of 2004, accounted for 79.4% of the erosion weakening area. Moderately eroded weaken-
ing area accounted for 19.1% of the erosion weakening area, which mainly transition into non-apparently eroded area, and this part area accounted for 93.9% of the Moderately eroded weakening area.

Table 2. The transition matrix of area of different erosion intensity from 2004 to 2009.

|       | 2004    | 2009    | 2004-Sum |
|-------|---------|---------|----------|
|       | 1       | 2       | 3        | 4        | 5        | 6        | 6         | 2009-Sum |
| 1     | 1015.6312 | 110.0439 | 24.6251  | 1.1628   | 0.3171   | 0.0338   | 1151.8139 |
| 2     | 40.9296  | 13.2514  | 1.5765   | 0.1714   | 0.0220   | 0.0006   | 55.9515   |
| 3     | 48.2145  | 14.5478  | 4.8166   | 0.2899   | 0.0912   | 0.0165   | 67.9765   |
| 4     | 12.2057  | 3.7510   | 0.7511   | 0.1589   | 0.0157   | 0.0235   | 17.1705   |
| 5     | 3.6013   | 1.3250   | 0.3601   | 0.0220   | 0.0006   | 0.0000   | 5.5644    |
| 6     | 0.2756   | 0.2157   | 0.0577   | 0.0873   | 0.0157   | 0.0235   | 0.6755    |
|       | 1120.8579| 143.1348 | 32.1876  | 2.3118   | 0.5858   | 0.0744   | 1299.1523 |

Note: The data in the upper triangular matrix represented the area of soil erosion weakening from 2004-2009.

The data in the lower triangular matrix represented the area of soil erosion exacerbating from 2004-2009.

The data on diagonal line represent no change of erosion intensity. The following tables were the same.

Table 3. The transition matrix of area of different erosion intensity from 2009 to 2014.

|       | 2009    | 2014    | 2009-Sum |
|-------|---------|---------|----------|
|       | 1       | 2       | 3        | 4        | 5        | 6        | 6         | 2014-Sum |
| 1     | 1132.9059 | 6.6782  | 8.6085   | 4.5195   | 1.2740   | 0.0704   | 1154.0565 |
| 2     | 7.5927  | 47.3389 | 1.9160   | 1.3992   | 0.0782   | 0.0000   | 58.3250   |
| 3     | 8.5952  | 1.6029  | 56.8174  | 0.9783   | 0.4961   | 0.0071   | 68.4970   |
| 4     | 1.7798  | 0.2985  | 0.3912   | 10.1547  | 0.1350   | 0.0122   | 12.7714   |
| 5     | 0.8692  | 0.0330  | 0.2326   | 0.111    | 3.0100   | 0.5689   | 4.8247    |
| 6     | 0.0711  | 0.0000  | 0.0108   | 0.0078   | 0.5711   | 0.0169   | 0.6777    |
|       | 1151.8139 | 55.9515 | 67.9765  | 17.1705  | 5.6447   | 0.6755   | 1299.1523 |

Table 4. The transition matrix of area of different erosion intensity from 2004 to 2014

|       | 2014    | 2004    | 2014-Sum |
|-------|---------|---------|----------|
|       | 1       | 2       | 3        | 4        | 5        | 6        | 6         | 2014-Sum |
| 1     | 1019.1658 | 108.8447| 24.5482  | 1.1235   | 0.3349   | 0.0394   | 1154.0565 |
| 2     | 42.0473  | 14.5028 | 1.5915   | 0.1647   | 0.0181   | 0.0006   | 58.3250   |
| 3     | 47.7186  | 15.3610 | 5.0648   | 0.2611   | 0.0813   | 0.0102   | 68.4970   |
| 4     | 8.8725   | 2.7660  | 0.6056   | 0.5103   | 0.0170   | 0.0000   | 12.7714   |
| 5     | 2.8330   | 1.3985  | 0.3153   | 0.1660   | 0.1119   | 0.0000   | 4.8247    |
| 6     | 0.2207   | 0.2618  | 0.0622   | 0.0862   | 0.0226   | 0.0242   | 0.6777    |
|       | 1120.8579| 143.1348| 32.1876  | 2.3118   | 0.5858   | 0.0744   | 1299.1523 |
The severely eroded weakening area accounted for 1.1%, and it mainly transited into non-apparently eroded area, which accounted for 72.5% of the severely eroded weakening area. The very severely and extremely eroded weakening area accounted for 0.4% of the erosion weakening area.

4 Conclusions
Yuyao city is the typical eroded area of Southeast coastal. Based on remote sensing and GIS integration technology, the pattern and dynamic evolution law of soil erosion from 2004–2014 in Yuyao city are analyzed. The conclusions were as follows:

In ten years, the total area of soil erosion had been decreasing. The average annual soil erosion area decreased rate was 3.3199km$^2$/a. It is worth noting that the decreasing trend of slightly eroded area was very obvious, but the moderately, severely, very severely and extremely eroded area were increasing. In recent years, on the one hand, Yuyao city vigorously carry out ecological management of soil erosion, to a certain extent, to curb soil erosion. But on the other hand, due to population growth on the increasing demand for land, steep slope cultivation, quarrying and other activities have caused serious soil erosion.

Through the analysis of the evolution law of erosion, it was found that the area of different erosion intensities was dynamic. In the first five years, the dynamic transition area was 264.8690km$^2$, erosion weakening area accounted for 52.2%. In the latter five years, the dynamic transition area was 48.9085km$^2$, which accounted for 45.3% of the transition area. The dynamic transition area of ten years was 259.7725km$^2$, and erosion weakening area accounted for 52.8%. The erosion weakening area was mainly derived from the slightly eroded area transited to the non-apparently eroded area. The erosion exacerbating area was mainly came from the transition of non-apparently eroded area to the slightly and moderately eroded area.

The main feature of the rural economic development in Yuyao city is planting economic forest on the steep slope. In the process of economic forest construction, the farmers only pursue the area increasing and economic growth, ignore the soil and water conservation, and weed out grass under economic tree causing soil surface bareness. When rainstorm occurred, the soil erosion under economic tree is very serious. In the comprehensive scientific investigation of soil erosion and ecological security, Experts put forward the special erosion phenomenon of the "Green hill viewing at a distance, soil erosion near viewing". Soil erosion leads to the decline of soil fertility, and seriously affect the growth of fruit tree. At the same time, it also leads to the pollution of water resources. The soil erosion has reduced the productivity of the orchard. Some orchards have even become wasteland, which is not conducive to regional economic development and social progress.

In the remote sensing images, the status of vegetation in Yuyao city is very good, the coverage is relatively high. But because the forest structure is unreasonable and the lack of understory shrubs or herbaceous vegetation, the high bare degree of soil surface, the phenomenon of moderate or even more severe soil erosion will also happen. Thus, it is necessary to carry out the soil erosion control of the economic forest in Yuyao city.

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