

## The Soil Erosion Distribution Characteristics and Ecological Background of Chinese Cultivated Land

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**Abstract:** The soil erosion of cultivated land was analyzed by the remote sensing survey data in 1995. 33.15% of the cultivated land was eroded. Water erosion area took up 88.43% and wind erosion was 11.08%, frozen erosion was 0.32%, gravitation erosion was 0.04% and engineering erosion was 0.13%. Dry land was mainly and paddy field was less. The serious water erosion of dry land was located mainly in loess plateau, Yunnan plateau, Sichuan and southern hill area and wind erosion was located in west-northern and east-northern area. The water erosion of paddy field was distributed in southern-west area and wind erosion was in Heilongjiang and Liaoning provinces. Frozen erosion was distributed in Inner Mongolia and Qinghai-Tibet plateau. The engineering and gravitation erosion of Guangdong was most serious. The paper studied the relationship between water erosion of dry land and topography, vegetation and precipitation. *EI*(Ecological environment index) and *SEI*(Soil erosion intensity index) was built to study their relevance. When *EI* was smaller than 4.33, there were strong relevance between them.

**Keywords:** cultivated land, soil erosion, spatial distribution characteristics, ecological environment index, soil erosion intensity index

The paradox between human beings and land is predominant in China with 0.103 hm<sup>2</sup> cultivated land per capita<sup>[1]</sup>. At the same time only 41.33% of the cultivated land is not restricted and the slope of 4.5% is more than was 25<sup>o</sup>[2]. 38% is eroded by water<sup>[3]</sup>. The annual ruin area owing to soil erosion, desertation and salinity is 1.347 × 10<sup>5</sup>hm<sup>2</sup> which is equivalent to 16% of the decreasing land<sup>[1]</sup>. Hence, it is of most significance to study the spatial distribution of soil erosion and control measures by remote sensing survey.

Soil erosion type includes water, wind, frozen, gravitation, engineering erosion. Water and wind erosion is the main erosion type and the area of water erosion is the largest in China. The influencing factors of soil erosion include climate, topography, morphology, vegetation and surface materials and human activities. The relevance between soil erosion intensity and ecological environment index is studied by the remote sensing survey results.

### 1 Data source and soil erosion classification standard

In order to investigate the soil erosion condition and protection measures of the cultivated land, the soil erosion survey was done by interpreting TM imagery of 1995 and 1996 in China. Landsat TM imagery was composed, projected, rectified and interpreted to get the 1:100,000 vector data of the national land use and the soil erosion map with the help of field investigation, topography, vegetation, soil quality, sand, soil erosion map. The provincial maps were collected into the national level.

**Table 1 The soil erosion classification system in China**

Erosion type	Erosion intensity					
1 Water erosion	11 Trivial	12 Light	13 Moderate	14 Intensive	15 Highly intensive	16 Serious
2 Wind erosion	21 Trivial	22 Light	23 Moderate	24 Intensive	25 Highly intensive	26 Serious
3 Frozen erosion	31 Trivial	32 Light	33 Moderate	34 Intensive		
4 Gravitation erosion	40					

The soil erosion was classified into water erosion, wind erosion, frost erosion, gravitation erosion and engineering erosion in terms of the national standard issued in 1996<sup>[4]</sup>. The soil erosion intensity was classified into six grades.

**Table 2 The soil erosion intensity classification standard**

Grade	Average erosion modulus (t/(km <sup>2</sup> • a))	Average erosion depth (mm/a)
1 Trivial	<200,500,1,000	< 0.74
2 Light	200,500,1,000—2,500	0.74—1.9
3 Middle	2,500—5,000	1.9—3.7
4 Intensive	5,000—8,000	3.7—5.9
5 Serious	8,000—15,000	5.9—11.1
6 Highly serious	>15,000	>11.1

## 2 The soil erosion of cultivated land and spatial distribution characteristics

### 2.1 The soil erosion of cultivated land

75.05% of cultivated land is dry land and 24.95% is paddy field in China<sup>[2]</sup>. The raster data of cultivated land and soil erosion map are combined to get the soil erosion distribution. From Tab.3 42.48% of the dry land was eroded while 7.92% of the paddy field was eroded. Totally, 33.15% of the cultivated land was eroded. The water force erosion took up 88.43% of all the eroded cultivated land, the wind erosion was about 11.08%, frozen erosion was 0.32%, gravitation erosion was 0.04% and engineering erosion was 0.13%.

**Table 3 The soil erosion of the cultivated land in China**

Erosion type	Water erosion					Wind erosion					Frozen	Gravitation	Engineering	Total	
Erosion intensity	12	13	14	15	16	22	23	24	25	26	30	40	50		
Paddy field	4.80	2.30	0.52	0.05	0.01	0.08	0.08	0.01				0.01		0.06	7.92
Dry land	15.03	13.27	6.15	2.00	0.86	2.24	2.04	0.46	0.21	0.02	0.15	0.01		0.04	42.48
Cultivated land	12.27	10.31	4.63	1.48	0.63	1.66	1.51	0.34	0.16	0.01	0.11	0.01		0.04	33.15

### 2.2 The soil erosion of dry land

The eroded cultivated land by water forces was mainly located in Sichuan, Heilongjiang, Gansu, Shaanxi, Inner Mongolia, Yunnan, Shanxi, Guizhou and Chongqing. They concentrated in the Loess plateau, Yungui plateau and Sichuan mountain area. In Chongqing municipality, Guizhou, Sichuan and Gansu provinces the eroded percentage was more than 80%. That of Shaanxi, Yunnan, Ningxia, Inner Mongolia, Fujian and Shanxi was more than 51%. The water eroded dry land in Heilongjiang took up about 38.14% of that of Chinese cultivated land because its dry land was large. The highly serious water erosion located mainly in Loess plateau and Yunan, Guizhou, Sichuan, Fujian and Jiangxi mountain area. The acreage of the wind eroded dry land was located in Inner Mongolia, Jilin, Heilongjiang, Hebei, Henan, Xinjiang and Gansu province which took up about 91.66% of the national wind erosion. Inner Mongolia was the most serious area by the wind erosion and the eroded percentage was more than 36.1%. The percentage of Jilin, Ningxia, Xinjiang and Hebei provinces was more than 7%.

### 2.3 The soil erosion of paddy field

More mountain and hill areas were distributed in Sichuan, Yunnan, Guizhou, Anhui, Heilongjiang, Guangxi, Hubei and Zhejiang and were the main water erosion areas in China. The water eroded paddy field was more than 10% in Yunnan, Guizhou and Sichuan province. The wind eroded paddy field in Heilongjiang took up about 55.12% and Liaoning was 9.2%, Hubei 7.83%, Jilin 7.35%, Inner Mongolia 6.52%. The wind eroded areas were located in Northern China. In Inner Mongolia the wind eroded paddy field was about 9.12%.

### 2.4 The frozen, engineering and gravitation soil erosion

The frost erosion happened in the coldest areas including Inner Mongolia, Tibet and Qinghai which took up about 82.77%、16.76% and 0.34% of Chinese frost erosion acreage respectively. Engineering erosion was caused by mining、quarrying、building and other activities. The engineering erosion in dry land was the most serious in Guangdong province whose percentage took up 58.01% and Heilongjiang was 14.21%. The engineering erosion in paddy field in Guangdong was about 59.29% of China and Fujian was 15.39%. A great amount of cultivated land was converted into urban、rural settlements and the construction land. The engineering erosion extended without agricultural field protection measurements. The gravitation in Guangdong was the most serious with the rapid development of the cities. In Chongqing municipality and Hunan province the slope cultivated land caused the gravitation erosion.

## 3 The relationship between soil erosion of cultivated land and ecological environment

### 3.1 Soil erosion intensity index(SEI)

Soil erosion intensity is affected by all kinds of natural and human factors. The most famous experiential model is universal soil erosion equation<sup>[5,6]</sup>. Precipitation, soil erodibility, topography, vegetation and protection measures are considered by the model. Topography, vegetation and precipitation are chosen as the ecological environmental factors.

The equation of soil erosion intensity index(SEI) is built as follows:

$$SEI_j = \frac{\sum_{i=1}^n D_{ij} A_{ij}}{\sum_{i=1}^n A_{ij}} \quad (1)$$

Where,  $SEI_j$  is the soil erosion intensity index in  $j$  state,  $D_{ij}$  is the soil erosion coefficient in  $j$  state as the soil erosion intensity is  $i$  grade,  $A_{ij}$  is the erosion area of the ecological factor in  $j$  state when the soil erosion intensity is grade  $i$ .

The soil erosion coefficient is calculated by the average model. When water and wind erosion is trivial, the coefficient is 2; when the erosion is light, middle, intensive, serious and highly serious, the coefficient of soil erosion is 4, 8, 16 and 32. The coefficient of gravitation erosion is 16 and that of engineering erosion is 4.

Ecological environmental index(EI) is built as follows:

$$EI = \frac{\sum_{i=1}^n W_i E_i}{n} \quad (2)$$

Where,  $EI$  is the ecological environment index,  $W_i$  is the weight of ecological environmental factor  $i$ ,  $E_i$  is grade of ecological factor,  $n$  is the number of ecological factors.

### 3.2 Single factor analysis

At the same time the single factor of soil erosion is used to study soil erosion.

#### (1) Topography

The slope was divided into 6 grades by the 1:250,000 slope vector map and data sets. There was a strong relevance between the slope and the soil erosion intensity index. The higher the slope was, the higher the soil erosion intensity was.

**Table 4 Grade of the slope and the relationship to the soil erosion intensity**

Slope	0—5	5—8	8—15	15—25	25—35	35—90
Slope grade	1	2	3	4	5	6
Soil erosion intensity( <i>SEI</i> )	1.47	3.29	4.42	5.31	6.24	7.29

#### (2) Vegetation index

NOAA/AVHRR data sets are used to study vegetation condition. NDVI(Normalized Difference Vegetation Index) <sup>[7,8]</sup> was gotten by the NOAA data to represent the vegetation condition and was classified into 8 grades. The equation is as (3). The higher the grade, the better the vegetation. When the NDVI was 3, *SEI* was the highest; when the vegetation was 2, 8, 4, 7, the *SEI* was the second; when the vegetation index was 1 where the climate was dry and the precipitation was the lowest, *SEI* was the lowest.

$$NDVI = \frac{CH1 - CH2}{CH1 + CH2} \quad (3)$$

**Table 5 Grade of NDVI and the relationship to the soil erosion intensity**

NDVI	-0.1—0	0—0.1	0.1—0.2	0.2—0.3	0.3—0.4	0.4—0.5	0.5—0.6	0.6—1.0
NDVI Grade	1	2	3	4	5	6	7	8
Soil erosion intensity( <i>SEI</i> )	0.49	4.52	6.45	2.35	1.56	1.44	2.09	3.90

#### (3) Precipitation

The precipitation is divided into 6 grades by the agricultural climate zoning standard<sup>[9]</sup>. *SEI* was the highest when the precipitation was 1,000 mm—1,600 mm where was humid. *SEI* was second in the territory where it was half-humid and the precipitation was 400 mm—800 mm. *SEI* was the third when the climate was half-arid and the precipitation was 250 mm—400 mm. The soil erosion intensity was the lowest in the place where the grade of the precipitation was 4, 6 and 1.

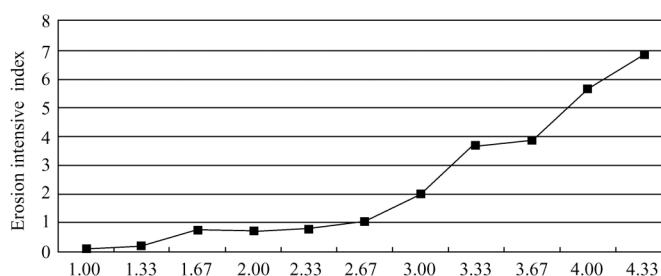
**Table 6 Grade of precipitation and the relationship to the soil erosion intensity**

Precipitation/mm	< 250	250—400	400—800	800—1,000	1,000—1,600	>1,600
Precipitation grade	1	2	3	4	5	6
<i>SEI</i>	0.26	2.05	2.90	0.80	4.70	0.42

### 3.3 The relationship between soil erosion intensity and ecological environmental index

The soil erosion intensity was affected by the combination of the topography, vegetation, soil quality and precipitation. When  $E_i$  was  $\leq 4.33$ , the relationship between the ecological factors and the soil erosion intensity was highly relevant. The higher the ecological index, i.e. the slope was higher, the vegetation was worse and the precipitation was less, the more serious the soil erosion intensity. When the

ecological index was  $> 4.33$ , the relevance was not high and the soil erosion intensity was more affected by the single ecological factor.



**Fig. 1** Ecological environmental index

#### 4 Conclusions

The soil erosion of cultivated land was analyzed by the remote sensing survey data in 1995. 33.15% of the cultivated land was eroded. Water erosion and wind erosion are the main types. Dry land was mainly and paddy field was less. The serious water erosion of dry land was located mainly in loess plateau, Yunnan plateau, Sichuan and southern hill area and wind erosion was located in west-northern and east-northern area. The water erosion of paddy field was distributed in southern-west area and wind erosion was in Heilongjiang and Liaoning provinces. Frozen erosion was distributed in Inner Mongolia and Qinghai-Tibet plateau. The engineering and gravitation erosion of Guangdong was most serious. The paper studied the relationship between water erosion of dry land and topography, vegetation and precipitation.  $E_i$  (Ecological environment index) and  $SEI$  (Soil erosion intensity index) was built to study their relevance. When  $E_i$  was smaller than 4.33, there were strong relevance between them.

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