Analysis of Soil retention service function in the North Area of Guangdong based on the InVEST model

Xiuming Wang¹, Xucheng Liu¹, Yingxian Long¹, Wei Liang¹, Jian Zhou¹, Yinbo Zhang*

¹South China Institute of Environmental Sciences, the Ministry of Ecology Environment of PRC, NO. 7 West Street, Yuancun, Guangzhou 510655, China.
* Corresponding author’s email: zhangyinbo@scies.org

Abstract. Based on the InVEST model, the spatial and temporal evolution trends of water and soil conservation service functions in northern Guangdong in the three periods from 2000 to 2018 were evaluated, and the factors affecting the changes and spatial distribution of soil conservation time were further analyzed. The results indicate: (1) The average soil erosion per unit area in the study area in different years is 5.9~7.6 t/ha•a, 81~87% of the study area is mild erosion. (2) The amount of soil retention per unit area in the study area increased firstly and then decreased, reaching a maximum of 68.87 t/ha•a in 2010. This change was mainly caused by the difference in rainfall erosivity caused by precipitation. (3) The low-value areas of soil retention in the study area are mainly distributed in the central urban areas of Shaoguan, Qingyuan, Naxiong Basin and Wengjiang Basin. The high-value areas are mainly distributed in the mountainous areas, such as Dadong Mountain, Qiweishan Mountain, Luoke Mountain, Huashui and Huangsi-nao Mountain. (4) The main factors affecting the spatial difference of soil retention in the study area are land use type, altitude, and slope. Under different land use types, the amount of soil retention per unit area from large to small is woodland> grassland> water area> cultivated land> construction land.

1. Introduction
Soil conservation is the function of ecosystems (such as forests, grasslands, etc.) to reduce soil erosion caused by water erosion through its structure and process, and is one of the important adjustment services provided by ecosystem[1]. The function of soil and water conservation was calculated by the Universal Soil and Water Loss Equation (USLE) in the previous research. Since the USLE model does not consider the ability of the block to intercept upstream sediments, there are some problems in the calculation results of this method. The InVEST model of ecosystem services is jointly developed by Stanford University, World Wide Fund for Nature (WWF) and Nature Conservation Society (TCN). Its sediment delivery ratio module (SDR) takes the ability of the block itself to intercept upstream sediments into consideration, therefore the evaluation results are more reasonable, and the results can be spatially visualized to further study its spatial distribution characteristics. At present, Chinese scholars Liu Dongqing[2], Liu Xiaona[3], He Shasha[4], Dang Hong[5], Wang Sen[6], etc. have used the model to study the the soil retention function of Bailong River Basin, Mentougou District, Taihang Mountain Qi River Basin, the Gongcheng River Basin, Yan'an City and other places.

2. Overview of the study area
The study area is located in the middle and upper reaches of Beijiang River and south of Nanling, including Qingyuan and Shaoguan City, with an area of 37,457 km². The river system in the study area is rich, and the Beijiang River runs from north to south. The main tributaries are Zhenjiang River, Wujiang River, Mojiang River, Jinjiang River, Nanshui River, Wengjiang River, Pajiang River, Lianjiang River, and Binjiang River. The climate is a mid-subtropical humid monsoon climate. The average annual rainfall is 1630-2400mm, and the average annual temperature is 18.8-22.0 °C. The regional zonal soil is red soil, and yellow soil is distributed at an altitude above 700 meters; subtropical evergreen broad-leaved forest below 800m above sea level, deciduous broad-leaved forest at 800-1300m, and conifer-broad mixed forest at 1300-1600m.

In 2019, the Guangdong Provincial Development and Reform Commission integrated 18 natural reserves at the junction of Qingyuan and Shaoguan City in the study area to establish Special Ecological Reserve in northern Guangdong, as an important mean to strengthen the ecological barrier in northern Guangdong. Northern Guangdong is an important water conservation area in Guangdong Province. At the same time, the study area is a key prevention area for soil erosion in Guangdong Province. Since 2000, with the acceleration of urbanization and industrialization in Guangdong Province, human interference increased, land use patterns changed, bringing about changes in the structure and function of the ecosystem. This study is based on the InVEST model to evaluate the spatial and temporal changes of soil conservation functions in northern Guangdong, and to study the factors impacted the soil conservation functions, in order to provide a reference for its ecological conservation policy.

3. Data resources and Research method

3.1 Date resources
(1) Land use data: The land use data for 2000, 2010, and 2017 comes from the Resource and Environment data Cloud platform of the Chinese Academy of Sciences (http://www.resdc.cn/), including 22 secondary land-use type with a spatial resolution of 1km; (2) The rainfall data comes from the National Meteorological Information Center (http://data.cma.cn/) China Surface Climate Data Daily Value Data Set (V3.0 ), Including daily data from the study area and surrounding meteorological stations in 2000, 2010 and 2016, analyzed and processed to form monthly data, and through kriging spatial interpolation to form a raster layer with a spatial resolution of 1km; (3) Soil texture data comes from Cold and Arid Regions Scientific Data Center (http://westdc.westgis.ac.cn/) Chinese soil data set with a spatial resolution of 1km; (4) The elevation data comes from the Geospatial Data Cloud (http://www.gscloud.cn/), the spatial resolution is 30m.

3.2 InVEST model
The sediment delivery ratio module (SDR) of the InVEST model calculates the potential soil erosion and sediment yield based on terrain and climatic conditions firstly, and then calculates the actual erosion and actual sediment yield based on vegetation coverage factors and soil and water conservation measures. The soil retention is $RKLS_x$ minus $USLE_x$. 

$$SD = RKLS - USLE$$

$$RKLS_x = R_x \times K_x \times LS_x$$

$$USLE_x = R_x \times K_x \times LS_x \times C_x \times G_x$$

$$R_x = \sum_{i=1}^{12} 1.735 \times 10^{1.5 \log P_x}$$

$$K = (0.2 + 0.3 e^{(-0.0256SN(1-SIL))}) \times \left(\frac{SIL_{CLA}}{SIL} + SIL\right)^{0.3} \times \left(\frac{1-0.25C}{C+e^{3.72-2.93C}}\right) \times \left(\frac{1-0.7SN}{SN+e^{-5.51+2.25SN}}\right)$$

In the formula, $RKLS_x$ is the potential soil erosion amount of grid x, and $USLE_x$ is the actual soil erosion amount of grid x, which mainly considers the vegetation coverage, interception effect and the calculation results after implementing soil and water conservation measures; $R_x$ is the rainfall erosion force; $K_x$ is the soil erodibility; $LS_x$ is the slope length factor; $C_x$ is the vegetation coverage factor; $G_x$ is the soil and water conservation measures factor. $P_x$ represents precipitation, $P_x$ represents
precipitation, SAN、SIL、CLA、C are the content of sand, powder, clay and organic carbon, respectively. \( SN1=1-SAN \).

The input layers for running the sdr model include: (1) Elevation data of the study area. (2) Rainfall erosion grid layer. (3) Soil erodibility factor grid layer. (4) Land use classification layer. (5) Watershed, Based on DEM data, using the Hydrology analysis tool in the ArcGIS toolbox, by analyzing flow direction, flow accumulation, and flow length, a watershed layer is generated, with a total of 111 sub-watersheds.(6) Biophysical Table, including \( C_\text{x} \) and \( G_\text{x} \), which is cited from related studies\(^{[1,7,8,9]}\).

4. Results and discussion

4.1 analysis of Time-space change trend

(1) Soil Erosion Intensity

From 2000 to 2017, the actual soil erosion per unit area in the study area was 5.95, 7.64, and 4.75 t/ha·a, showing an upward trend and then a downward trend. According to "Soil Erosion Classification Standards" (Table 1, Figure 1), most of the study area belongs to mild erosion, and the proportion of mild erosion area in three years is basically maintained at 81-87%.

| classification of soil erosion | Soil erosion modulus (t/ha·a) | Proportion of area in 2000(%) | Proportion of area in 2010(%) | Proportion of area in 2017(%) |
|-------------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| Mild erosion                  | 0≤usle<10                   | 85.35                       | 81.86                       | 87.87                       |
| Light erosion                 | 10≤usle<25                  | 9.43                        | 4.38                        | 8.28                        |
| moderate erosion              | 25≤usle<50                  | 3.32                        | 7.44                        | 2.55                        |
| Strong erosion                | 50≤usle<80                  | 1.03                        | 4.22                        | 0.74                        |
| Very Strong erosion           | 80≤usle<150                 | 0.60                        | 1.16                        | 0.41                        |
| Severe erosion                | Usle≥150                    | 0.26                        | 0.91                        | 0.15                        |

(2) Soil Retention

From 2000 to 2017, the soil retention per unit area of the study area was 52.64, 68.87, and 43.16t/ha·a, showing an upward trend and then a downward trend.

In terms of spatial distribution, the spatial distribution of soil retention in the three years is basically the same. The low-value areas are mainly distributed around the central city of Shaoguan, including Zhenjiang, Wujiang, southern Renhua, and southeast of Lechang; the central city of Qingyuan, including Qingcheng and east of Qingxin, Nanxiong Basin and Wengjiang Basin. The high-value areas are mainly distributed in the Dadong Mountains at the junction of Lechang and Yangshan, Qiwei Mountain at the junction of Lianshan and Liannan, Luoke Mountain in the south of Yangshan, Yaoing Mountain in Shixing, and the Huashui Mountain and Huangshanao Mountains in Yingde. It can be seen that the areas with low soil retention are mainly distributed in the flat plains and basins in the area, where the land use types are mainly cultivated land, and the human activities are frequent. The areas with high soil retention are mainly distributed in the mountainous areas, where the land use type is mainly forest land, with less human interference.
Figure 1 The actual soil erosion and soil retention quantity in the study area from 2000 to 2017 (t/ha·a)

4.2 Analysis of Impacting Factors

4.2.1 Factors affecting the time change of soil retention. According to the calculation principle of the model, the main factors affecting the interannual change of soil retention may be meteorological factors, land use types, etc. As can be seen from Figure 2, rainfall erosion and the proportion of forest area are consistent with the annual soil retention changes.

In order to further analyze the main factors affecting soil retention, under the meteorological conditions in 2000, the average soil retention in the study area in 2010 and 2017 was 52.75 and 52.81 t/ha·a respectively, that is, under the same meteorological conditions, the annual soil retention is
almost the same, indicating that the main factor causing the differences in soil retention between the years is meteorological factors, which is consistent with related studies\cite{10}.

Figure 2 Correlation between soil retention and affecting factors

4.2.2 Factors affecting the spatial distribution of soil retention.

(1) Soil retention of different land use types

Using the onal statistics function in ArcGIS to count soil retention under various land-use types, the results showed that the soil retention per unit area from large to small is forestland> grassland> farmland> water area> construction land, of which forestland soil retention per unit area reached 49.95t/ha·a, 1.5~2times of grassland and cultivated land, which is consistent with related studies\cite{2,4}.

Figure 3 The different land types of Soil retention per hectare in study area (t/ha·a)

(2) Soil retention of different altitudinal gradients

Using natural breakpoint method in ArcGIS to divide elevation data into seven categories, and using the zonal statistic tool to count the soil retention under different altitude gradients, it can be seen that with the increase of altitude, the soil retention shows an overall upward trend (Table 2).

(3) Soil retention of different slope

Table 2 was obtained by using the method described above, it can be seen that with the increase of slope, the soil retention per unit area shows a continuous upward trend, mainly due to the better vegetation coverage measures in areas with higher slopes, consistent with relevant studies\cite{4,7}.

Table 2 The different altitudinal gradients and slope of Soil retention in study area (t/ha·a)

| Altitude (meters) | Soil retention per hectare (t/ha·a) | Slope(°) | Soil retention per hectare (t/ha·a) |
|-------------------|-------------------------------------|----------|-------------------------------------|
|                   | 2000 | 2017 | 2000 | 2017 |
| farmland          | 23.4| 20.8| 23.4| 20.8|
| forest            | 61.6| 50.0| 61.6| 50.0|
| grassland         | 35.0| 15.3| 35.0| 15.3|
| water area        | 18.8| 18.8| 18.8| 18.8|
| used land         | 9.3 | 11.9| 9.3 | 11.9|
| Soil retention in 2000 (t/ha·a) | Soil retention in 2017 (t/ha·a) |
|-----------------------------|-------------------------------|
| 1717~1790                  | 41.85                         | 1327~1482                   | 24.23                        |
| 1790~1852                  | 61.32                         | 1482~1544                   | 38.9                         |
| 1852~1912                  | 55.9                          | 1544~1605                   | 45.13                        |
| 1912~1967                  | 56.1                          | 1605~1662                   | 46.74                        |
| 1967~2020                  | 51.2                          | 1662~1723                   | 42.15                        |
| 2020~2074                  | 41.8                          | 1723~1809                   | 7.34                         |
| 2074~2149                  | 43.7                          | 1809~2010                   | 9.17                         |

(4) Soil retention of different precipitation gradients

It can be seen from Table 3 that under different precipitation gradients, the average soil retention per unit area in the study area has no obvious change.

**Table 3** The different precipitation gradients of Soil retention in study area (t/ha·a)

5 Conclusions

In this paper, the InVEST model is used to evaluate the spatial-temporal variation pattern and influencing factors of the soil conservation service function in northern Guangdong. The results showed that: (1) The average soil erosion per unit area in the study area in different years is 5.9 ~ 7.6 t/ha·a, 81 ~ 87% of the study area is mild eroded. (2) The amount of soil retention per unit area in the study area increased firstly and then decreased, reaching a maximum of 68.87 t/ha·a in 2010. This change was mainly caused by the difference in rainfall erosivity caused by precipitation. (3) The low-value areas of soil retention in the study area are mainly distributed in the central urban areas of Shaoguan, Qingyuan, Nanxiong Basin and Wengjiang Basin. The high-value areas are mainly distributed in the Dadong Mountains, Weishan Mountain, Luoke Mountain, Yaoling Mountain, Huashui mountain and Huangsi-nao Mountains. (4) The main factors affecting the spatial difference of soil retention in the study area are land use type, altitude, and slope. Under different land use types, the amount of soil retention per unit area from large to small is forest > grassland > farmland > water area > construction land; soil retention is positively correlated with elevation and slope, that is, with the increase of slope and altitude, the amount of soil retention showed an upward trend.

References

[1] Min Li 2016 Ecosystem Services Evaluation Based on InVEST Model: A Case Study of Yanqing, Beijing(China). [2] Dongqing Liu, Jie Gong, Jinqian Zhang, Xuecheng Ma 2018 Research of Water and soil Conservation 25(4)98-103. [3] Xiaona Liu, Xia Pei, Long Chen, Chunlan Liu 2018 Research of Water and soil Conservation 25(6)168-173.
[4] Shasha He, Wenbo Zhu, Jingjing Zhang, Lupei Ye 2018 *Journal of Henan University*(Natural Science) **48**(5)542-552.

[5] Hong Dang, Lijuan Ge, Chuanyan Zhao, Jiyang Qi 2018 *Journal of Labzhou University*(Natural Science) **54**(5)633-639.

[6] Sen Wang 2018 *Study on Land Use Change and soil Conservation Function in Yan’an City Based on InVEST model Application*(University of Chinese Academy of Sciences).

[7] Biao Li 2017 *Ecosystem Services Evaluation of Nanliujiang River Basin Based on GIS and InVEST Model* (Guangxi Teachers Education University).

[8] Shanshan Chen 2016 Evaluation of Ecological Service Functions of Water Retention and Soil Conservation in Water Sources Area for the South-to-North Water Transfer——A case study in Shangluo City (Northwest University).

[9] Fangfang Jia 2014 *InVEST model Based Ecosystem Services Evaluation with case study on Ganjiang River Basin* (China University of Geosciences(Beijing)).

[10] Conghong Huang 2014 *Ecosystem Services Evaluation Based on InVEST Model: Case Studies in Baoxing County, Sichuan and Mentougou District, Beijing* (Beijing Forestry University).