Surface soil loss change monitoring - Taking the Dachaoling Watershed as an example

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Abstract. A nationwide project on soil loss change monitoring was successfully performed in 2018 in China, and a special technical regulation was developed for the purpose of unified approach and high-quality outcomes from the project. Taking the Dachaoling Watershed as an example, this paper aims to discuss the reasons for surface soil loss change by the monitoring approach which is from the technical regulation and includes steps of data preparation, surface soil erosion factor analysis, soil erosion analysis, soil loss change analysis, and countermeasures and suggestions for reducing soil loss. First, landuse, soil and water conservation measures for 2018 were extracted from remote sensing image of high spatial resolution while vegetation cover for 2018 from Landsat TM and MODIS NDVI product - MOD13Q1 data; second, surface soil erosion factors for were analysed for China Soil Loss Equation (CSLE) based on the outputs of first step; third, CSLE was used to make analysis on surface soil loss in the selected watershed; fourth and finally, transition matrix analysis method to make analysis on surface soil loss change from 2011 to 2018 and the reasons. The results indicate that the soil loss change monitoring approach is practicable and effective; landuse changes are both chief affecting factor and main controlling ways to soil loss; and human actions changing landuse need to be more cautious and far-sighted in the future.

1. Introduction
China has been troubled by serious soil loss due to special natural and geographical conditions coupling with a long-time excessive use of land and water resources, the area of soil erosion was 2.95 million km², among which water erosion and wind erosion covered 1.29 million km² and 1.66 million km² respectively [1]. Therefore, much attention has been paid to soil conservation to reduce soil loss and improve environment. On one hand, great achievements and improvements have been made for strenuous efforts in the past years; on the other hand, China is still in the process of urbanization, industrialization and modernization, problems of population, resources and environment are conspicuous and continual, and new soil erosion increasingly occurred, which made it urgent and important to obtain accurate, temporal, spatial information on soil loss. Many valuable studies were conducted in this field to find out effective measures for soil and water conservation, using remote sensing survey [2], sampling survey [3-4], and comprehensive measures [5]. Most of these studies mainly concentrated on landuse change [6-9] to perform investigation and assessment on soil loss [6-10]. In 2018, a nationwide project on surface soil loss monitoring was carried out as planed in China, with the purpose of obtaining detailed information of soil loss change and the corresponding reasons, and seeking for more appropriate measures. A series technical documents were developed to gain high quality outputs from this project, among which, the Technical Regulation on Regional Soil Loss
Dynamic Monitoring (Trial) [11] (hereinafter referred to as the Technical Regulation) is the most important one, providing detailed guidance on data demands, technical approaches on soil loss change monitoring for water erosion, wind erosion and frost-thaw erosion, as well as the requirements for various outputs. In this paper, the Dachaoling Watershed was selected as an example to study the reasons for surface soil loss change using the monitoring approach from the Technical Regulation.

The Dachaoling Watershed, located in Fangshan District of Beijing, with drainage area of 25.38 km², has the peak of 1165m in the south and lowest bottom of 323m at the mouth of main channel in the north, with relative height difference of 842m, total valley length of 10.82km, and valley density of 0.43km/km² (See Figure 1). The main rocks compose of limestone and sandstone, and soils of mountain brown soil and meadow soil, vegetation of temperate deciduous broad-leaved forest with slight coniferous forest, shrub and grass. In 2011, the landuse included only forest, grass, and construction, with area of 25.12 km², 0.24 km², and 0.02 km², respectively. However, the landuse in 2018 expanded to tillage, orchard, forest, grass, construction, transportation, and water, areas of each landuse type were 0.17 km², 1.68 km², 21.52 km², 1.25 km², 0.1 km², 0.01 km², and 0.65 km², respectively. Hence, human actions in this watershed were considerably active during the period from 2011 to 2018, it is representative to select this watershed as example to demonstrate surface soil loss change monitoring.

![Figure 1. Remote sensing image and valleys.](image1)

2. Approach and data acquirement for surface soil loss monitoring
The points closely related to this study in the Technical Regulation include: (1) landuse is classified as 8 types (tillage, orchard, forest, grass, construction, transportation, water, and others) and 25 subtypes, while soil and water conservation measure is classified as 2 types (eco-measures, structural measures) and 20 subtypes (mainly various terracing, fruit pits, silt arrester, check dam); (2) information for landuse and measures should be extracted from remote sensing image with high spatial resolution, for vegetation cover from Landsat TM data and MODIS NDVI product - MOD13Q1 data, keeping continuous 3 years before the monitoring year, and (3) soil loss analysis for water erosion should be performed using Chinese Soil Loss Equation (CSLE).

2.1. Surface soil erosion modulus estimation
Beijing belongs to water erosion area [12], and soil loss modulus estimation should be computed using CSLE according to requirements for water erosion of the Technical Regulation, as mentioned above.
As a transformation and localization of Universal Soil Loss Equation (USLE) in China [13], CSLE is written as follow:

\[ A = RKLSBET \]  

where, \( A \)-soil erosion modulus, \( t/(hm^2\cdot a) \), indicating the annual soil loss amount in unit surface area; \( R \)-the rainfall erosivity factor, calculated by the summation of the erosion index EI30 over the period of evaluation; \( K \)-the soil erodibility factor, reflecting the susceptibility of a soil type to erosion; \( L \)-the slope length factor; \( S \)-the slope gradient factor; \( B \)-the vegetation cover and management factor; \( E \)-the soil and water conservation measure factor; \( T \)-the tillage measure factor.

Based on the measured data at typical runoff stations, Ansai, Zizhou, Lishi and Yanan in the Loess Plateau in China [13,14], CSLE has been developed with the advantages of intending to cover sheet erosion, rill erosion, interrill erosion and gully erosion, combining the actual situations of soil and water conservation measures, separating two factors of \( C \) (protective coverage of canopy and organic material factor) and \( P \) (Soil conservation operations or other measures factor) in USLE into three factors (\( B \), \( E \), and \( T \)), as well as enhancing the easy operability of the equation.

2.2. Technical approach on surface soil loss monitoring

Soil erosion modulus is the fundamental for soil loss intensity assessment, hence, the technical approach on soil loss monitoring focuses on the soil loss modulus computation. Figure 2 presents the framework of surface soil loss change monitoring that is composed of five steps: 1) data preparation, 2) surface soil erosion factor analysis, 3) soil erosion analysis, 4) soil loss change analysis, and 5) countermeasures and suggestions for reducing soil loss.

**Step 1**, data preparation. In this step, the data need to be prepared include geographic, remote sensing image, soil and water conservation data, all of them should be collected and pre-processed to satisfy the requirements for soil erosion factor analysis. Landuse types and soil and water conservation measures are the key information for soil erosion factor analysis and need to be extracted from remote sensing data and identified as accurate as possible based on existing soil conservation data.

**Step 2**, soil erosion factor analysis. Based on the outputs of the first step, this step performs soil erosion factors needed by CSLE, including factors from precipitation, landuse, vegetation cover, landform and soil conservation measure and tillage measure. The outputs from step 2 contain seven factors: rainfall erosivity factor \( R \), soil erodibility factor \( K \), slope length factor \( L \), slope factor \( S \), vegetation cover and biological measure factor \( B \), soil and water conservation measure factor \( E \), tillage measure factor \( T \).

**Step 3**, soil erosion analysis. Based on the outputs of step 2, this step conducts soil erosion modulus calculation using CSLE and conducting soil loss intensity assessment using a national standard, named Standards for classification and gradation of soil erosion [15]. The soil erosion intensity is classified as seven levels: micro soil erosion, mild erosion, moderate erosion, strong erosion, extreme erosion, and severe erosion. And the area of soil erosion intensity is or over mild erosion will be regarded as area of soil loss.

**Step 4**, soil loss change analysis. In this step, the change of soil loss, based on the loss in a certain time, will be analyzed according to each erosion level. Commonly, transition matrix analysis is used to perform this analysis to get detailed information on area of soil loss level change and of each landuse type change.

**Step 5**, countermeasure and suggestion service. Based on outputs of the above steps, some appropriate countermeasure and suggestions to reduce soil loss will be come up with in this step, especially for area of extreme erosion, and severe erosion.

2.3. Data acquirements on surface soil loss monitoring

The following data should be acquired for soil erosion factor computation and erosion intensity assessment: rainfall record data, soil properties, geographic data, landuse data, soil and water conservation measure data, and vegetation cover data.
Data for landuse, soil and water conservation measures, and vegetation cover, were from remote sensing interpretation. Remote sensing image (GF2) of 0.8m spatial resolution in the second half of 2017 was utilized to extract information on landuse, and soil and water conservation measures for 2018; and Landsat TM data and MODIS (Moderate-resolution Imaging Spectroradiometer) NDVI product - MOD13Q1 data from 2015-2017 (continuous 3 years before the monitoring year), were used by remote sensing fusion method to extract information on vegetation cover for 2018. All the data process (interpolation or resampling in ArcGIS software) and computation were performed for entire Beijing area. Hereinafter, all outputs for the Dachaoling Watershed were clipped by watershed boundary from entire Beijing area map.

The other data were collected directly from related departments. It needs to be noted that the results of surface soil erosion intensity in 2011 were from reference [16], not performed in this study.

3. Surface soil erosion estimation in the Dachaoling Watershed

The estimation on surface soil loss includes three steps: surface soil erosion factor analysis, soil erosion modulus computation, and soil erosion intensity evaluation.

3.1. Analysis on surface soil loss factor

3.1.1. Rainfall erosivity factor \( R \)

Rainfall erosivity factor \( R \) indicates the capacity of separating and transporting soil particle due to raindrop and runoff resulting from rainfall, with unit of \( \text{MJ}\cdot\text{mm}/(\text{hm}^2\cdot\text{h}\cdot\text{a}) \).

The method for point rainfall erosivity factor is as follow [11]:

\[
\bar{R} = \sum_{i=1}^{12} \bar{R}_{\text{obs}}
\]

\[
\bar{R}_{\text{hm}} = \frac{1}{N} \sum_{i=1}^{12} \sum_{j=0}^{2} (\alpha \cdot P_{i,j,k})
\]

\[
\bar{W\bar{R}_{\text{hm}}} = \frac{\bar{R}_{\text{hm}}}{\bar{R}}
\]

where, \( \bar{R} \)- annual mean rainfall erosivity capacity, \( \text{MJ}\cdot\text{mm}\cdot\text{hm}^2\cdot\text{h}^{-1}\cdot\text{a}^{-1} \); \( \bar{R}_{\text{hm}} \)-the rainfall erosivity capacity in k-th half month, \( \text{MJ}\cdot\text{mm}\cdot\text{hm}^2\cdot\text{h}^{-1} \); \( P_{i,j,k} \) - the j-th erosive daily rainfall amount of the k-th half month in the i-th year, mm; \( P_{i,j,k} \) will be 0 if there is no erosive daily rainfall in a certain half month in a year, namely, \( j=0 \), \( P_{i,0,k}=0 \); \( \alpha \) is a parameter, \( \alpha=0.3937 \) in warm season (May to September) and \( \alpha=0.3101 \) in cold season (October to December, and January to April in the next year); \( \bar{W\bar{R}_{\text{hm}}} \)-the proportion of the mean rainfall erosivity capacity in the k-th half month \( (\bar{R}_{\text{hm}}) \) to that in the entire year \( (\bar{R}) \); i, j, k-the subscript for repeat computation, where, \( i=1, 2, \ldots, N \) refer to the time series from 1 to 30; \( j=0, \ldots, m \), refer to the days with erosive rainfall (daily rainfall amount over 12mm) of the k-th half month in the i-th year; \( k=1, 2, \ldots, 24 \), refer to the serial number of half months in a year.

In this study, the daily rainfall record data of 83 rainfall stations in Beijing from 1986 to 2015, lasting for continuous 30 years and satisfying the data requirements of the Technical Regulation [11], were used to make analysis on rainfall erosivity factor. The values of the rainfall erosivity factor was interpolated for entire Beijing area using Kriging method in ArcGIS software package, and Figure 3 presents the R factor map of the Dachaoling Watershed.

3.1.2. Soil erodibility factor \( K \)

Soil erodibility factor \( K \), \( \text{t}\cdot\text{hm}^2\cdot\text{h}/(\text{hm}^2\cdot\text{MJ}\cdot\text{mm}) \), relating to the physical and chemical properties of soil, indicates the resistance capacity of soil to raindrop and runoff to detach soil particles.

Generally, the Technical Regulation provides two methods to compute soil erodibility factor. The first one is standard observation method [17], that is, obtaining the soil loss amount under unit rainfall
erosion capacity by standard runoff plot with slope length of 22.13m, slope gradient of 9%, regular and frequent remove of weed and soil crust, and without tillage and vegetation cover rate less than 5%.

The second one is to estimate using the following formula [18] with enough soil samples:

\[
K = 0.0726 \left(2 + 0.3e^{-0.0256 \cdot \text{SAN}(1-\frac{22.13}{\text{m}})}\right) \left(\frac{\text{SIL}}{\text{CLA+3IL}}\right)^{0.19(1-0.25C)} (1 - 0.75 \cdot \text{SN1}) + 0.0102
\] (5)

where, K-soil erodibility factor, t·hm\(^{-2}\)·h/(hm\(^{-2}\)·MJ·mm), SAN, SIL and CLA-the contents of sand, silt and clay, SN1=1-SAN/100, C-the content of organic carbon, computed by content of organic (OM), C=OM/1.724.

In this study, 115 soil samples, from 82 sites in 7 mountainous districts of Beijing, were collected to measure the grain size distribution and organic content, and then further to compute soil erodibility factor K using formula (5) [16]; then, the values of soil erodibility factor K was interpolated for entire Beijing area using Kriging interpolation method, and Figure 4 presents the K factor map of the Dachaoling Watershed.

3.1.3. Slope length factor L
Slope length factor L, dimensionless, refers to the ratio of surface soil loss amount at a certain slope length to that at a slope length of 22.13m with same other conditions (precipitation, soil, slope gradient, landuse and measures for water and soil conservation and tillage), indicating the influence of slope length to surface soil erosion [11].

\[
L = \frac{L_{i}^{m+1} - L_{i}^{m+1}}{(22.13)^{m}}
\] (6)

\[
m = \begin{cases} 
0.2 & \theta \leq 1^\circ \\
0.3 & 1^\circ < \theta \leq 3^\circ \\
0.4 & 3^\circ < \theta \leq 5^\circ \\
0.5 & \theta > 5^\circ 
\end{cases}
\] (7)

The DEM data with 10 meters spatial resolution was used in this study to obtain the L factor with threshold of 100 meters for slope length according to the landform situation in Beijing, and Figure 5 presents the L factor map of the Dachaoling Watershed.

3.1.4. Slope gradient factor S
Slope gradient factor S, dimensionless, refers to the ratio of surface soil loss amount at a certain slope gradient to that at a slope gradient of 9% with same other conditions (precipitation, soil, slope length,
landuse and measures for water and soil conservation, and tillage), indicating the influence of slope to surface soil erosion.

In this study, slope factor \( S \) was calculated using the following formula [11],

\[
S = \begin{cases} 
10.8 \sin \theta + 0.03 & \theta < 5^\circ \\
16.8 \sin \theta - 0.5 & 5^\circ \leq \theta < 10^\circ \\
21.9 \sin \theta - 0.96 & \theta \geq 10^\circ 
\end{cases} 
\tag{8}
\]

where, \( \theta \) is slope and \( S \) is slope gradient factor.

A correction for slope factor \( S \) in practical operation is as follow: The slope gradient factor \( S \) is to be computed using the first item of formula (8) \((\theta < 5^\circ)\) if only the landuse types of land parcels are garden plot, forestland, or grassland [9]. Figure 6 presents the slope gradient factor \( S \) in the Dachaoling Watershed.

\[
\text{Figure 5. Slope length factor } L. \quad \text{Figure 6. Slope gradient factor } S.
\]

3.1.5. Vegetation cover and biological measure factor \( B \)
Vegetation cover and biological measure factor \( B \), dimensionless, refers to the ratio of surface soil loss amount under vegetation cover to that of clean tillage with same other conditions (precipitation, soil, slope gradient, slope length, landuse and measures for water and soil conservation and tillage measure), indicating the influence of vegetation cover to surface soil erosion.

Seasonal change, vegetation type and vertical structure of vegetation cover contribute to soil erosion, hence, all of them should be taken into consideration when vegetation cover and biological measure factor \( B \) is computed.

Fractional Vegetation Cover (FVC) of 24 half months in a year was used to reflect annual change of vegetation cover in this project. And the first step to get FVC is to compute NDVI, as follow:

\[
NDVI = \frac{NIR-R}{NIR+R} \tag{9}
\]

Where, NDVI-normalized vegetation index; NIR-reflectivity in the near infrared band; R-reflectivity in the red band of visible light.

Based on the outputs of NDVI, Fractional Vegetation Cover were computed based on MODIS and TM image data as follow [11]:

\[
FVC = \frac{NDVI - NDVI_{\text{min}}}{NDVI_{\text{max}} - NDVI_{\text{min}}} \tag{10}
\]
where, FVC- Fractional Vegetation Cover, NDVI- Normalized Difference Vegetation Index, the pixel value of NDVI image, \(NDVImax\) and \(NDVImin\) were the values of NDVI for pixels covered by pure vegetation and pixels covered by pure bare soil.

Three types of landuse, garden plot, forestland, and grassland, were used for standing for vegetation type while FVC and GD were used for the vertical structure of vegetation cover. For other landuse type, such as tillage, construction, transportation, water, and others, the values of B factor are directly assigned according to the standard of the Technical Regulation.

The formula to compute B for garden plot, forestland, and grassland is as follow \[11\],

\[
B = \sum_{i=1}^{24} SLR_i \cdot WR_i
\]

where, \(WR_i\)-the proportion of the mean rainfall erosivity capacity in the \(i\)-th half month \((\overline{R}_{i\text{hm}})\) to that in the entire year \((\overline{R})\), range 0-1; \(SLR_i\)-the proportion of soil loss in the \(i\)-th half month \((\overline{R}_{i\text{hm}})\) to that in the entire year \((\overline{R})\) for garden plot, forestland, and grassland, dimensionless, range 0-1.

The formula for SLR for (1) tea garden plot and shrubland, (2) orchard and other garden, forest land and other woods land, and (3) grassland were as follows:

(1) tea garden plot and shrubland

\[
SLR_i = \frac{1}{1.7647+0.86242 \times 1.05905^{100 \times FVC}}
\]

(2) orchard and other garden, forest land and other woods land

\[
SLR_i = 0.44468 e^{-3.20096GD} - 0.04099 e^{FVC(1-GD)} + 0.025
\]

(3) grassland

\[
SLR_i = \frac{1}{1.25+0.78945 \times 1.05968^{100 \times FVC}}
\]

where, \(FVC\)- Fractional Vegetation Cover based on NDVI, range 0-1; \(GD\)-understory coverage of high forest, range 0-1, including understory coverages of all vegetation plants (orchard, herb, and withered litters) other than the canopy of high forest.

In this study, \(FVC\) for 24 half months in 2018 were first computed with Landsat TM data and MODIS NDVI product - MOD13Q1 data from 2015-2017 (continuous 3 years before the monitoring year). The reasons are as follow: (1) TM image has high spatial resolution of 30 meters but low temporal resolution while MOD13Q1 has the high temporal solution of 16 days but low spatial resolution of 250m. Therefore, combination of high spatial resolution of TM data and high temporal solution of MOD13Q1 was used by remote sensing images fusion method to get FVC with high spatial and temporal solution; (2) the purpose of image data lasting for 3 years is to remove possible large change in vegetation cover by averaging 3-year-FVC-data into in a year data, namely, the FVCs for 24 half months in one year.

Then, based on FVC, B factor was computed. The information of landuse from FVC to B, such as tea garden plot, shrubland, orchard and other garden, forest land and other woods land, and grassland, was from interpretation of remote sensing image.

The values of factor B was resampled for entire Beijing area, and Figure 7 presents the B factor map of the Dachaoling Watershed.

### 3.1.6. Soil and water conservation measure factor E

Soil and water conservation measure factor E, dimensionless, refers to the ratio of surface soil loss amount under certain soil and water conservation measures to that under no any soil and water conservation measure with same other conditions (precipitation, soil, slope gradient, slope length, landuse and tillage measure), indicating the role of soil and water conservation measures playing to surface soil erosion.

In this study the information of soil and water conservation measures was from interpretation of remote sensing image of second half of 2017. According to the technical regulation, the values of E factor are directly assigned according to the E factor table and Figure 8 presents the E factor map of the Dachaoling Watershed, in which red stands for terraced fields while green for level-terrace.
3.1.7. Tillage measure factor T

Tillage measure factor T, dimensionless, refers to the ratio of surface soil loss amount under certain tillage measures to that under no any tillage measure with same other conditions (precipitation, soil, slope, slope length, landuse and soil and water conservation measure), indicating the role of tillage measures playing to surface soil erosion.

According to the technical regulation, the values of T factor are directly assigned according to the T factor table [19]. Figure 9 presents the T factor map of the Dachaoling Watershed, in which green is on half of tillage area.

3.2. Surface soil erosion modulus computation

Computation for surface soil erosion modulus was performed using ArcGIS platform that need all of raster data of each soil loss factor to be prepared. Hence, the first step is to develop the raster data layer with 10meter spatial resolution for each soil loss factor by resampling all of the factor layers obtained.

The second step is to compute surface soil loss using China Soil Loss Equation with ArcGIS raster calculator. The surface soil erosion modulus for each grid was conducted by multiply operation using map algebra of multiplying rainfall erodibility factor R, soil erodibility factor K, slope length factor L, slope gradient factor S, vegetation cover and biological measure factor B, soil and water conservation measure factor E, and tillage measure factor T; then, make the raster data layer of soil erosion modulus with 10 meters spatial resolution.

As multiplication is performed for surface soil loss modulus, it should be noted that, tillage measure factor T is selected to times other five factors if the landuse type is tillage land, while vegetation cover and biological measure factor B is chosen to do this if the landuse type is other.

3.3. Surface soil loss intensity evaluation

Based on the outputs of surface soil erosion modulus, soil erosion intensity assessment was performed according to Standards for classification and gradation of soil erosion [15], that is, as for water erosion, the area with modulus less than 2 ton/(hm²·a) belongs to micro soil erosion, 2-25 ton/(hm²·a) to mild erosion, 25-50 ton/(hm²·a) to moderate erosion, 50-80 ton/(hm²·a) to strong erosion, 80-150...
ton/(hm²·a) to extreme erosion, and over 150 ton/(hm²·a) to severe erosion. Figure 10 presents the outputs of surface soil erosion intensity of the Dachaoling Watershed in 2018.

Figure 10. Soil erosion intensity in 2018.

Figure 11. Soil erosion intensity in 2011.

Figure 12. Soil erosion intensity change.

Figure 13. Landuse change.

4. Results and analysis

4.1. Surface soil erosion change

Figure 10 and Figure 11 present the surface soil erosion intensity of the Dachaoling Watershed in 2018 and 2011 separately. Figure 12 and Table 1 present the soil erosion level change between 2011 and 2018. The changes, indicated in the three figures and the table, is very obvious and presents three trends as follow. First, the area of soil loss increased. The soil loss area in 2011 was 7.59km², while that was 12.03km² in 2018, the increment of soil loss area reached 4.44 km², 58.5% of that in 2011. Second, the spatial location of soil erosion changed. Soil erosion occurred chiefly in south part (the upper reach area) of the watershed in 2011, but in most part of the watershed in 2018. Third, the intensity of soil erosion distinctly decreased. Figure 10 shows that the intensity of soil erosion was
moderate erosion to strong erosion within half of the erosion area while Figure 11 indicates that the intensity of soil erosion was mild erosion within most of the erosion area with very small area of moderate erosion, and Table 1 presents that the areas of moderate erosion and strong erosion decreased 3.59 km$^2$ and 2.55 km$^2$, respectively.

**Table 1.** Soil loss change in the Dachaoling Watershed from 2011 to 2018.

| Soil erosion intensity | 2011 | Total (2018) |
|-----------------------|------|--------------|
|                       | Micro| Mild | Moderate | Strong | Micro | Mild | Moderate | Strong |
| 2018                  | 9.76 | 0.90 | 1.36     | 1.33   | 13.35 |
|                       | 7.97 | 0.49 | 2.28     | 1.23   | 11.97 |
|                       | 0.05 | 0.00 | 0.00     | 0.00   | 0.05  |
|                       | 0.01 | 0.00 | 0.00     | 0.00   | 0.01  |
| Total (2011)          | 17.79| 1.39 | 3.64     | 2.56   | 25.38 |
| Change (2018-2011)    | -4.44| 10.58| -3.59    | -2.55  | /     |

4.2. Reasons for surface soil erosion change

From above we can see that obvious changes on surface soil erosion have occurred in the Dachaoling Watershed during the period from 2011 to 2018. Landuse changes, being the chief factor affecting soil loss and the main ways to change soil loss for man, are the most possible reason for surface soil erosion change. The reasons can be analyzed as follow.

At the macro level, the reasons for the change are as two aspects. On one hand, much endeavors have been paid to soil and water conservation and great effects achieved. First, many projects for soil and water conservation have been implemented since 2011, such as national key project for soil and water conservation, wind-sand source comprehensive controlling projects at watershed scale in North China, and so on. Second, supervisions have been strengthened greatly on human-induced soil loss, such as production and construction project, by modern information technologies and legal education, as well as all abandoned mines closing. Third, afforestation was also distinctly enhanced. According to statistics, the forest cover in Beijing increased over 900 km$^2$ from 2011 to 2017. All of these measures are quite helpful to soil loss prevent and relief. On the other hand, some factors are also contributed to surface soil erosion, for instance, frequent human actions in some abandoned mines and scattered locations, changes in landuse.

**Table 2.** Landuse change in the Dachaoling Watershed from 2011 to 2018.

| Landuse type | 2011          | Total (2018) |
|--------------|---------------|--------------|
|              | Tillage | Orchard | Forest | Grass | Construction | Transportation | Water |              |
| 2018         |         |         |        |       |             |               |       |              |
| Tillage      | 0.00    | 0.00    | 0.16   | 0.01  | 0.00        | 0.00          | 0.00  | 0.17         |
| Orchard      | 0.00    | 0.00    | 1.64   | 0.03  | 0.01        | 0.00          | 0.00  | 1.68         |
| Forest       | 0.00    | 0.00    | 21.37  | 0.15  | 0.00        | 0.00          | 0.00  | 21.52        |
| Grass        | 0.00    | 0.00    | 1.24   | 0.01  | 0.00        | 0.00          | 0.00  | 1.25         |
| Construction | 0.00    | 0.00    | 0.08   | 0.01  | 0.01        | 0.00          | 0.00  | 0.1          |
| Transportation | 0.00  | 0.00    | 0.01   | 0.00  | 0.00        | 0.00          | 0.00  | 0.01         |
| Water        | 0.00    | 0.00    | 0.62   | 0.03  | 0.00        | 0.00          | 0.00  | 0.65         |
| Total (2011) | 0.00    | 0.00    | 25.12  | 0.24  | 0.02        | 0.00          | 0.00  | 25.38        |
| Change (2018-2011) | 0.17  | 1.68    | -3.6   | 1.01  | 0.08        | 0.01          | 0.65  | /            |
At the micro level, landuse change is the most possible reason for surface soil erosion change in this watershed. As is well-known, landuse/landcover changes play an important role in evapotranspiration, rainfall interception of canopy, filling on the surface, and infiltration in soil, as well as concentration and evolution of runoff in channel, which are important to soil loss. Figure 13 and Table 2 present the landuse change information in the Dachaoling Watershed from 2011 to 2018. The table indicates that the forest land decreased by 3.6 km² while orchard land, grassland and water increased 1.68, 1.10 and 0.65 km², respectively. Obviously, the human actions in the watershed were considerably active, and the decrement from forest land to orchard, grassland result in new occurrence of soil loss in the watershed.

5. Conclusions
Taking the Dachaoling Watershed as an example, an entire process to perform the surface soil loss change monitoring was presented with reason analysis on soil loss change in view of landuse change in this study. Here come the conclusions as follow.

(1) The outputs identify the basic situation of soil loss change in the Daochaoling Watershed. Obviously, the area of soil loss increased from 7.59 km² in 2011 to 12.03 km² in 2018, and soil erosion moved from the south part (the upper reach area) of the watershed in 2011 to all most part of the watershed in 2018, and the intensity of soil erosion distinctly decreased in general, showing the improvements of soil and water conservation in the watershed.

(2) Landuse changes, closely related to soil loss change, are the chief factor affecting soil loss, as well as the main ways to change soil loss. In the Daochaoling Watershed, the decrement from forest land to orchard, grassland result in new occurrence of soil loss, but various terracing measures decreased the soil loss intensity. On the large scale, for entire Beijing area, not same to that in the Dachaoling Watershed, both the area and the intensity of moderate and strong erosion decreased by a large margin during these years. The reasons for this change were analyzed in section 4.2. Therefore, human actions on landuse have double-side roles in soil loss change and need to be more cautious, far-sighted and helpful to soil and water conservation.

(3) The soil loss change monitoring approach is practicable and effective. The core of this approach is CSLE, in which all of the factors contribute to surface soil erosion are taken into consideration, including rainfall erosivity, soil erodibility, slope length, slope gradient, vegetation cover and biological measure, soil and water conservation measure and tillage measure. The results indicate that outputs of the project from the approach are reasonable, while it should be refined at some technical consideration, such as too rough consideration on soil and water conservation measure factor and tillage measure factor, and the approach will be improved greatly in the coming future based on the experiences of a great deal of continuous practices.

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