Remote sensing monitoring on soil erosion based on LUCC in Beijing mountain areas

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Abstract. The eco-environmental problems caused by land use and land cover change have been a severe block to regional sustainable development in the Beijing mountain areas. In this study, two temporal Landsat TM images in 2002 and 2009 were used, the soil erosion factors included vegetation coverage, slope and land use were calculated. The soil erosion degree was divided into six levels, micro, mild, moderate, strong, intensive and severe. The raster data with 30 m × 30 m pixels small-class of the soil erosion map was used to extract soil erosion information. This thesis evaluated soil erosion dynamic in Beijing mountain areas based on land use and land cover change with the combination of technologies and methodologies of multi-temporal satellite remote sensing, GIS and field investigation. The soil erosion change and their driving forces were analysed. The results showed micro and mild soil erosion mainly existed in the Beijing mountain areas. The moderate erosion emerged in the areas with both slope and poor vegetation cover. The strong, intensive and severe soil erosion were rare but distributed in mountainous areas in Huairou, Miyun, and Mentougou. The soil erosion situation has improved markedly due to environment management from 2002 to 2009.

1. Introduction
Soil erosion is one of the world’s eco-environmental problems. The loss of the top fertile soil causes soil degradation, and therefore agriculture production, and the lowered water quality in river, lake, reservoir. Early studies on soil erosion have been performed globally \cite{[1-6]}, indicating soil erosion being closely related with change in land use change. For example, following the change of vegetation types and vegetation coverage, soil erosion can be retarded or aggravated \cite{[7,8]}

As the major water protection and supply regions and agricultural economic products base, the environment of mountain areas in Beijing have been ecological fragile. In the recent 20 years, land use and land cover changes had occurred markedly due to rapid economy development in Beijing mountain areas. The eco-environmental problem had been a severe block for the sustainable development in the region. In this study, based on land use and land cover change, the spatial distribution quantified soil erosion in Beijing mountain areas has been revealed with the combination of the technologies and methodologies of multi-temporal satellite remote sensing and GIS. The research would provide the basis for soil erosion control project and its technical measures, and promote and upgrade the level of the regional environment management.

2. Study area and Data
2.1. The study area

The fan shaped mountain areas are located in west, north and northeast of Beijing, China, including Fangshan, Mentougou, Yanqing, Huairou, Miyun, Changping and Pinggu. The geographic coordinate is between 115°05′ ~117°10′ E and 39°10′ ~ 41°57′ N. The area is 16808km², approximately accounts for 62% of the total areas of Beijing. The mountain terrain is roughly stepped down, successively in middle mountain, lower mountain, highland, table downland and piedmont diluvial fan. The distributions of soil and vegetation show the characteristics of vertical zonality. There are dense meadow vegetation cover and mountain meadow soil above 1800~1900 meters altitude, needle broad-leaved mixed forest zones and mountain brown soil in 800~1600 meters, poor mountain vegetation cover and thick bony brown soil or leached drab soil under 800 meters. The mountain areas are warm temperate zone with semi-arid continental monsoon climate and rainfall concentration. The weathers are windy and dry in spring, hot and rainy in summer, cool in autumn and dry and cold in winter. With torrential flood, the steep slope and thin soil, the large-scale land use and land cover change had aggravated soil erosion.

2.2. The data used

For this study case, mainly, two temporal LandsatTM images On May 22, 2002, September 22, 2009 and DEM data with 90 meters resolution were selected. GIS data of Beijing administrative boundary data were used.

2.3. Image processing

With the support of ENVI4.7, the preprocessing of remote sensing images had been done. That included the georectification to correct the geometric distortions, the image registration and subset, enhancement (contrast stretching, filtering). By the image classification supervised (Maximum Likelihood), the maps of land use had been obtained and the multi-temporal dynamic information of land use change had been extracted. In ArcGIS, the DEM data was used to extract slope.

3. Methodology

3.1. Extraction of soil erosion Impact factors information

First of all, based on the impact of land use and land cover change on soil erosion[9-10], in consideration of the natural conditions and soil erosion situation in Beijing mountain area, the vegetation coverage, the slope and land use were selected as the impact factors for soil erosion evaluation, and the information of Impact factors was extracted.

3.1.1. Extraction of Vegetation coverage factor and classification

The normalized difference vegetation index and vegetation coverage was been processed in the below equation.

\[ NDVI = \frac{NIR - R}{NIR + R} \]  \hspace{1cm} (1)

Equation (1), NDVI is the normalized difference vegetation index. NIR is near infrared band brightness value. R is red band brightness value.

\[ f_v = \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \]  \hspace{1cm} (2)

Equation (2) the \( f_v \) is vegetation coverage rate, NDVI_{min} and NDVI_{max} represent the minimum and maximum of normalized difference vegetation index.

According to the vegetation type and vegetation coverage in Beijing mountain area, The vegetation coverage were divided into seven grades for soil erosion evaluation. The grading was shown in table 1.
Table 1. The grading of vegetation coverage in Beijing mountain areas

| Grade | Vegetation coverage | Types of land use and land cover               |
|-------|---------------------|-----------------------------------------------|
| 1     | > 70                | forest and grass with high coverage rate      |
| 2     | 60–70               | forest, grass and orchard with mid coverage rate |
| 3     | 40–60               | forest, grass and orchard with low and medium coverage rate |
| 4     | 30–40               | forest, grass and orchard with low coverage rate |
| 5     | 20–30               | cultivated land                               |
| 6     | 10–20               | unused land, Wasteland, tidal flats           |
| 7     | <10                 | water area and construction land              |

3.1.2. Slope factor and classification

Soil erosion mainly existed in poor vegetation land and farmland with incline, especially soil erosion is most serious in the sloping farmland. In the various types of landforms, the slope had more impact on erosion intensity, and the slope was the most important factors. When the degree is less than 10, there are not more difference of erosion. When the degree is more than 10, soil erosion intensity increased with the slope. In this study, the slope was classified into 7 levels in Beijing mountain areas, and the table 2 showed the slope grading.

Table 2. The slope grading in Beijing mountain areas

| Slope classification |
|----------------------|
| grade               |
| 1                   |
| 2                   |
| 3                   |
| 4                   |
| 5                   |
| 6                   |
| 7                   |
| slope°)             |
| <5°                 |
| 5°~10°              |
| 10°~15°             |
| 15°~25°             |
| 25°~35°             |
| 35°~45°             |
| >45°                |

3.1.3. Land use factor

In view of the resolution of remote sensing images and the actuality of land use in the study area, land cover were divided into six types. They were forest and grass land, orchard land, cultivated land, unused land, construction land and water areas. In accordance with the difference of impact of land use and land cover on soil erosion intensity, the numerical value were assigned all kinds of land cover respectively, and they were converted to raster data in the ArcGIS9.3.

3.2. Extraction of soil erosion information and thematic map

According to soil erosion classification standard (SL190-96) issued by Ministry of Water Resources of the People's Republic of China, combined with the feature of images and field investigation, the interpretation signs of soil erosion were established, and the grades of soil erosion in Beijing mountain area were divided into six level, micro, mild, moderate, strength, strong and intense. The thematic maps of soil erosion were generated by overlay land use map, the slope grading map and vegetation coverage map in ArcGIS9.3. The distribution and the intensity of soil erosion in Beijing mountain area in 2002 and 2009 were presented in figure 1. The two temporal soil erosion information were be extracted by use the raster data with 30 m × 30 m unit, and combine graphics small-class of the soil erosion map in 2002 and 2009. As shown in table 3.
Table 3. The soil erosion areas in Beijing mountain areas from 2002 to 2009

|       | Micro   | Mild    | Moderate | Strong  | Intensive | Severe erosion |
|-------|---------|---------|----------|---------|-----------|----------------|
| 2002  | 6419.08 | 4354.07 | 1040.00  | 229.06  | 41.64     | 17.46          |
| 2009  | 7906.31 | 3686.88 | 355.00   | 145.02  | 29.15     | 17.36          |

Figure 1. The soil erosion map in Beijing mountain areas from 2002 to 2009

4. Result and discuss

4.1. The change in area and intensity of soil erosion

In 2002, the soil erosion area in total was 12101.31 km² in Beijing mountain areas with the micro soil erosion area of 6419.08 km², accounting for 53.04% of total soil erosion area and with mild soil erosion area of 4354.07 km², accounting for 35.98%. In 2009, the soil erosion area in total was 12139.72 km² with the micro soil erosion area of 7906.31 km², accounting for 65.13% of the total area and with the mild soil erosion area of 3686.88 km², accounting for 30.37%. From 2002 to 2009, the proportion of moderate erosion area decreased from 8.59% to 2.92%. The results showed that most of the soil erosion in Beijing mountain area fell into the category of micro and mild degrees. The strong to severe degree soil erosion was rarely distributed in Beijing mountainous areas. The reduction tendency in soil erosion intensity was presented.

4.2. Soil erosion spatial distribution and its variation

From the soil erosion maps of two periods, it was clear that micro and mild soil erosion existed in every district or county. The moderate erosion emerged in the mountain slopes and in the areas with poor vegetation cover. The strong, intensive and severe soil erosion mainly distributed in mountainous areas in Huairou, Miyun, Mentougou. From 2002 to 2009, large changes on the spatial distribution of soil erosion had taken place, soil erosion situation had been improved markedly in 2009.

4.3. Driving force of soil erosion change
Generally, the driving factors of soil erosion include natural factors and human factors. The results showed that human factors were the main driving force of soil erosion and its change during period of supervision in this study. Human factors were main reason to lead soil erosion from strong to severe degree in Huairou, Miyun, Mentougou mountainous areas. For example, the mining of mines, the quarries, the construction of highway and railway had destroyed vegetation and led to exacerbated soil erosion. From 2002 to 2009, small watershed comprehensive management was run in key areas in Huairou and Miyun; Miyun reservoir upstream was set as state-level key area of soil and water conservation; and small watershed management and ecological restoration were enhanced in Mentougou and Fangshan. Correspondingly, the soil erosion area and intensity had decreased significantly in Tanghe, Baihe river basin of Huairou, middle of Chaohe, and surrounding of Miyun reservoir.

5. Conclusion
The results showed that micro and mild soil erosion were main types of soil erosion in Beijing mountain areas. The moderate erosion emerged on the mountain slopes and in the areas with poor vegetation cover. The strong, intensive and severe soil erosion was rarely distributed in mountain areas in Huairou, Miyun, Mentougou. The soil erosion situation had been improved markedly from 2002 to 2009.

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