Research on Landform Classification of Beijing-Tianjin-Hebei Region Based on SRTM Remote Sensing Image Data

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Abstract. In this paper, Beijing-Tianjin-Hebei region was selected as the research area, and ArcGIS geographic information system was used as a platform to study the elevation data of SRTM-1 in the study area and draw the elevation classification thematic map. The neighborhood analysis method is used to classify the terrain relief and draw the classification map of undulation degree. Using window analysis and mean-point change analysis, the Python module programming is used to automatically extract the best statistical units for topographic relief, and reference is made to the past landform morphological division criteria. Combined with the actual landforms in this area, the topographic relief and DEM are used for the best statistical unit, the study area is divided into 3 categories: plain basin area, low mountain and hilly area, and plateau mountainous area, the classification map of the Beijing-Tianjin-Hebei area is compiled and the area occupied by the various types of landscape is calculated. Compared with most of the current scholars who use SRTM-3 data, this study has improved the accuracy, enhanced the reliability of the topographic relief research and landform classification research, and provided the basis for geomorphological studies in the Beijing-Tianjin-Hebei region.

1. Introduction
This paper selects the Beijing-Tianjin-Hebei area as a research area, which is located between 36.0°N and 42.7°N latitude and 113.4°E -119.9°E longitude, with a total area of approximately 21.8km². The area on the west side of the area is the Taihang Mountains, the north side is the Bashang plateau, and the southern plains are spread. The terrain is generally high in the northwest and low in the southeast, showing obvious differences in the topography (Figure 1).
Figure 1. Location map of the study area

The surface relief of the Earth is called landform, also known as topography. The orthographic projection map showing the landform, ground plane location and elevation in a certain proportion is called a topographic map. The topographic map expresses elevation by altitude, and in areas with strong surface cutting, it is sometimes necessary to understand the geographical phenomenon or geomorphological evolution process. Relatively high difference, therefore not only need to compile the topographic map, but also need to compile the topographic relief map. The Geographical Survey and Mapping Committee of the International Geographical Association regard the topographic relief as an important indicator of landform morphology classification [1-3]. Topography is one of the key areas of research in geology and tectonic studies [2-5].

SRTM (shuttle radar topography mission) is the space shuttle radar topography mapping project. It was jointly completed by the United States (NASA, National Bureau of Image and Mapping), Germany and Italy, and based on the "Endeavour" space shuttle, using interference radar to intervene. For radar mapping, there are two SRTM data: SRTM-1 data, sampled at a 1 arc-second distance, with a horizontal resolution of 30m; SRTM-3 data, sampled at a distance of 3 arc-seconds, with a horizontal resolution of 90m. The global digital elevation model (DEM) that the data is ultimately acquired after processing. Many scholars have conducted geomorphological studies based on SRTM data [4-7], and the effect of DEM resolution on terrain factor values cannot be ignored [8-10].

Based on SRTM-1 data, this paper uses ArcGIS as a platform, adopts window analysis method and mean-variable point analysis method, and uses Python module programming to automatically extract the best statistical unit of topographic relief in the study area to divide the topography (Figure 2). Provide the basis for the study of geomorphology in the study area.
2. Physiognomy morphology principle

The digital elevation model (DEM) was generated using SRTM-1 data, the elevation model was classified, the overall topography features of the study area were analyzed, and the classification indicators were selected; then the overall fluctuation of the study area was obtained using the GIS neighborhood analysis method, according to the mean change point. Principles determine the best statistical unit, and then get the best value of the degree of undulation, and finally the landform classification and statistical area.

2.1. Height classification

The research area has various types of landforms. Xiaowutai Mountain in Zhangjiakou is the highest peak in the region, with an elevation of more than 2,800 meters. The SRTM-1 elevation value shows that the maximum altitude in the study area is 2841m. Combined with the classification criteria of the landform, the elevation range of the study area can be divided into 7 levels: <10m, 10~50m, 50~100m, 100~500m, 500~1000m, 1000 ~ 1500m, > 1500m, get the elevation classification thematic map (Figure 3).

2.2. Best Statistics Unit

Topographic relief refers to the difference between the maximum and minimum elevations within a unit area, and the neighborhood analysis method is used to obtain the multi-scale (unit area) relief, since the area of the neighborhood range in neighborhood computing can be large or small, changing the area of the neighboring area is equivalent to changing the scale of the terrain relief. Therefore, the relief of the terrain is scale-dependent, and multi-scale terrain relief needs to be calculated. A large number of studies have shown that finding the inflection point based on the change point analysis method, thus judging the best applicability of the best statistical unit [10-12]. Use the neighborhood analysis function of ArcGIS to calculate the relief degree of different grid sizes, and then use the mean change point method to find the inflection point, and finally, obtain and output the undulation data under the best statistics unit. Details as follows:
Using the NeighborhoodStatistic tool in the ArcGIS spatial analysis module, the digital elevation model of the study area is divided by a template size of $n \times n$ ($n=3, 4, 5, ..., 60$) grid sizes, from $3 \times 3$ starts to calculate the maximum and minimum height of the grid, and it is calculated to $60 \times 60$; then, using the Raster Calculator, subtract the minimum height from the maximum value in each $n \times n$ grid. The degree of undulation in the grid is determined from $3 \times 3$ to $48 \times 48$, and the degree of undulation in all $n \times n$ grids is analysed [11-13].
\[ \Delta H = h_{ij, \text{max}} - h_{ij, \text{min}} \]

Where: \( h_{ij, \text{max}} \) represents the maximum elevation value in the grid; \( h_{ij, \text{min}} \) represents the lowest elevation value in the grid, and \( \Delta H \) is the difference between the maximum and minimum heights in the grid.

Using ArcGIS's Python module, we get the correspondence between grid size and average terrain relief (Table 1).

**Table 1.** Correspondence between grid size and average terrain of the study area

| Number | Grid unit size | Average relief amplitude (m) | Area \(10^4 \text{m}^2\) | Number | Grid unit size | Average relief amplitude (m) | Area \(10^4 \text{m}^2\) |
|--------|----------------|-----------------------------|--------------------------|--------|----------------|-----------------------------|--------------------------|
| 1      | 2 \( \times 2 \) | 0.04                        | 0.36                     | 25     | 26 \( \times 26 \) | 6.08                        | 60.84                    |
| 2      | 3 \( \times 3 \) | 0.08                        | 0.81                     | 26     | 27 \( \times 27 \) | 6.56                        | 65.61                    |
| 3      | 4 \( \times 4 \) | 0.14                        | 1.44                     | 27     | 28 \( \times 28 \) | 7.06                        | 70.56                    |
| 4      | 5 \( \times 5 \) | 0.23                        | 2.25                     | 28     | 29 \( \times 29 \) | 7.57                        | 75.69                    |
| 5      | 6 \( \times 6 \) | 0.32                        | 3.24                     | 29     | 30 \( \times 30 \) | 8.10                        | 81.00                    |
| 6      | 7 \( \times 7 \) | 0.44                        | 4.41                     | 30     | 31 \( \times 31 \) | 8.65                        | 86.49                    |
| 7      | 8 \( \times 8 \) | 0.58                        | 5.76                     | 31     | 32 \( \times 32 \) | 9.22                        | 92.16                    |
| 8      | 9 \( \times 9 \) | 0.73                        | 7.29                     | 32     | 33 \( \times 33 \) | 9.80                        | 98.01                    |
| 9      | 10 \( \times 10 \) | 0.90                        | 9                         | 33     | 34 \( \times 34 \) | 10.40                       | 104.04                   |
| 10     | 11 \( \times 11 \) | 1.09                        | 10.89                    | 34     | 35 \( \times 35 \) | 11.03                       | 110.25                   |
| 11     | 12 \( \times 12 \) | 1.30                        | 12.96                    | 35     | 36 \( \times 36 \) | 11.66                       | 116.64                   |
| 12     | 13 \( \times 13 \) | 1.52                        | 15.21                    | 36     | 37 \( \times 37 \) | 12.32                       | 123.21                   |
| 13     | 14 \( \times 14 \) | 1.76                        | 17.64                    | 37     | 38 \( \times 38 \) | 13.00                       | 129.96                   |
| 14     | 15 \( \times 15 \) | 2.03                        | 20.25                    | 38     | 39 \( \times 39 \) | 13.69                       | 136.89                   |
| 15     | 16 \( \times 16 \) | 2.30                        | 23.04                    | 39     | 40 \( \times 40 \) | 14.40                       | 144.00                   |
| 16     | 17 \( \times 17 \) | 2.60                        | 26.01                    | 40     | 41 \( \times 41 \) | 15.13                       | 151.29                   |
| 17     | 18 \( \times 18 \) | 2.92                        | 29.16                    | 41     | 42 \( \times 42 \) | 15.88                       | 158.76                   |
| 18     | 19 \( \times 19 \) | 3.25                        | 32.49                    | 42     | 43 \( \times 43 \) | 16.64                       | 166.41                   |
| 19     | 20 \( \times 20 \) | 3.60                        | 36                       | 43     | 44 \( \times 44 \) | 17.42                       | 174.24                   |
| 20     | 21 \( \times 21 \) | 3.97                        | 39.69                    | 44     | 45 \( \times 45 \) | 18.23                       | 182.25                   |
| 21     | 22 \( \times 22 \) | 4.36                        | 43.56                    | 45     | 46 \( \times 46 \) | 19.04                       | 190.44                   |
| 22     | 23 \( \times 23 \) | 4.76                        | 47.61                    | 46     | 47 \( \times 47 \) | 19.88                       | 198.81                   |
| 23     | 24 \( \times 24 \) | 5.18                        | 51.84                    | 47     | 48 \( \times 48 \) | 20.74                       | 207.36                   |
| 24     | 25 \( \times 25 \) | 5.63                        | 56.25                    | 48     | 49 \( \times 49 \) | 21.61                       | 216.09                   |

The average point change analysis method is roughly as follows [12-13], with the sample sequence \( H_0 \)

1. Let \( i = 2, 3, 4, N \), divide the sample into two segments for each \( i \): \( X_1, X_2, \ldots, X_{i-1} \) and \( X_i, X_{i+1}, \ldots, X_N \). Calculate \( X_{i1} \) and \( X_{i2} \) and statistics for each sample:

\[
S_i = \sum_{i=1}^{i-1} (X_i - \overline{X_{i1}})^2 + \sum_{i=N}^{N} (X_i - \overline{X_{i2}})^2
\]  

2. Calculate the total sample statistics:

\[
\overline{X} = \frac{\sum_{i=1}^{N} X_i}{N} \quad S = \sum_{i=1}^{N} (X_i - \overline{X})^2
\]
Mean change point is a commonly used change point analysis method in statistics. The point where the maximum difference between the statistic S of the original sample and the statistic Si after the sample segment is called the change point, according to Figure 4, take 17×17 as the best statistical unit.

2.3. Topographic relief
The best statistical unit is 17*17, which can determine the best statistical area is 0.26km², and Arcgis can be used to calculate the topographic relief. Details as follows:

1) Load ArcGIS on the Spatial Analysis module, activate the DEM data, and use the Neighborhood Statistics tool in Spatial Analysis. Set the Statistic type to the maximum, the type of the neighbourhood is a rectangle, and the size of the neighbourhood is 17*17, you can get the maximum level of a rectangle with a neighbourhood of 17*17, denoted as A;

2) Repeat the previous step, only set the Statistic type value to the minimum value to obtain the minimum level of the DEM data, denoted as B;

3) Using the raster calculator under Spatial Analysis, the formula is [A]-[B], a new level is then obtained, and the value of each grid is the determined terrain relief value centered on this grid.

The topography of the study area is calculated and the maximum relief is 683m. According to the landform classification basis, the relief can be divided into 4 levels: 0~30m, 30~200m, 200~300m, 300~683m, get the topographic relief classification map (Figure 5).

3. Landform classification in the study area
According to the topographic conditions of the study area, the combination of altitude and topographic relief two indicators [14-16], the division of the topography, the SRTM-1 image shows that the total area of the study area is 21.8 km², and the landforms can be divided into 3 categories: plain basin area, low mountain and hilly area, and plateau high mountain area with an area of 9.62 km², 7.20 km², 4.99 km², respectively. 44%, 33%, and 23% (Figure 6).
Figure 5. Terrain classification thematic map of the study area of the study area.
4. Conclusions and discussions

(1) This paper is based on SRTM-DEM, data type is SRTM-1, using ArcGIS as a platform, window analysis method and mean-variable point analysis method, using Python module programming, automatically extract and calculate the best statistics of topographic relief in the study area. The unit determines 17×17 as the best statistical unit. The best statistical area for terrain relief is 0.26km², which can divide the terrain relief of the Beijing-Tianjin-Hebei region into 4 levels.

(2) According to China's geomorphological classification criteria, with reference to the two indicators of altitude and topographic relief, the landforms can be divided into three categories: plain...
basin area, low mountain and hilly area, plateau high mountainous area, with an area of 9.62km$^2$, 7.20km$^2$, 4.99km$^2$ respectively and 44%, 33%, and 23% of the total area of the study area respectively.

(3) SRTM-1 data plane accuracy ± 20m, height accuracy ± 16m. Compared with the previous SRTM-3 data used by relevant scholars, the accuracy has been improved, and the practicability of topographic relief research and geomorphological classification research has been strengthened. This study can provide a basis for geomorphological research in the Beijing-Tianjin-Hebei region.

Acknowledgements
Shandong Earthquake Agency Youth Project (JJ1705Y).
Shandong Earthquake Agency key research and development plan Project (YF1809).

References
[1] Michael A. Geomorphology and global tectonics [M]. London: John Wiley & Sons, Ltd. Press, 2000: 1.
[2] ZHU Zhongli, MO Duowen, XU Haipeng [J]. Reasarch of Soil and Water Conservation, 1999, 6 (4): 86.
[3] Summerfield M A. Geomorphology and Global Tectonics [M]. London: John Wiley & Sons, Ltd. Press, 1999.
[4] XU Jiongxin, LI Bingyuan, YANG Xiaoping, et al. Recent Progress in Geomorphology and Quaternary Geology China and Some Perspectives [J]. ACTA GEOGRAPHICA SINICA, 2009, 64 (11): 1375.
[5] ZHANG Huiping, YANG Nong, ZHANG Yueqiao, et al. Geomorphology of the Minjiang Drainage System (Sichuan, China) and its structural implications [J]. Quaternary Scicences, 2006, 26 (1): 126.
[6] QIAN Cheng, CUI Tianri, LI Linchuan, et al. Application of ASTER-GDEM Data in the Geomorphic Characteristics Analysis of Northern Great Higgnan Ling Mountains [J]. Journal of Geomechanics, 2013, 19 (1): 82.
[7] CHENG Sanyou, LIU Shaofegn, ZHANG Huiping, et al. DEM Analysis of the Tectonic geomorphology of the Dabie Orogenic Belt [J]. Journal of Geomechanics, 2005, 11 (4): 333.
[8] CHEN Junyong. Quality Evaluation of Topogr aphic Data from SRTM3 and GTOPO30 [J]. Geomatics and Information Science of Wuhan University, 2005, 30 (11): 941.
[9] GAO Qing, TANG Lixia, GU Xiaoping. Analysis of ArcGIS-based relief amplitude of the Wangmo River Watershed in Guizhou [J]. Science of Soil and Water Conservation, 2015, 13 (4): 9.
[10] LI Mengmeng, ZHAO Yuanyuan, GAO Guanglei1, et al. Effects of DEM resolution on the accuracy of topographic factor derived from DEM [J]. Science of Soil and Water Conservation, 2016, 14 (5): 15.
[11] ZHANG Wei, LI Ainong. Study on the Optimal Scale for Caculating the Relief Amplitude in China Based on DEM [J]. Geography and Geo-information Science, 2012, 28 (4): 8.
[12] HAN Haihui, GAO Ting, YI Huan, et al. Extraction of Relief Amplitude Based on Change Point Method: A Case Study on the Tibetan Plateau [J]. Scientia Geographica Sinica, 2012, 32 (1): 101.
[13] XIANG Jingtian, SHI Jiuen. A Statistical Method for Data Processing in Nonlinear Systems[M]. Beijing: Science Press, 1997.
[14] LI Bingyuan, Pan Baotian, Hank Jiafu. Basic Terrestrial Geomorphological Types In China and the Irircrum Scriptions [J]. Quaternary Sciences, 2008, 28 (4): 535.
[15] ZHAO Binbin, CHENG Yongfeng, DING Shijun, et al. Statistical Unit of Relief Amplitude in China Based on SRTM-DEM [J]. Journal of Hydraulic Engineering, 2015, 46 (S1): 284.
[16] CHEN Qiguang, SHAO Zhaogang, HAN Jianenal, et al. Statistical Unit of Relief Amplitude in China Based on SRTM-DEM [J]. Journal of Geomechanics, 2014, 20 (3): 304.