

Research Article

Soil Erosion Research Based on USLE in Great Khinggan

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Abstract: Based on the amended model of USLE universal soil loss equation and GIS technology, combined with the natural geographical features of Great Khinggan area, it has conducted quantitative analysis of the factor in Soil loss equation. Uses 2011 years TM/ETM images classification are land uses/cover type figure, combination Great Khinggan area Digital Elevation Model (DEM) and soil type distribution figure and research regional rainfall information, we gets all factors values of space distribution in the USLE model, gets soil erosion volume estimates data and soil erosion strength distribution figure based on grid cell data. Then according to S1190-96 of ratings standard (table) for ratings, obtained Great Khinggan area soil erosion strength grade distribution figure. Study results indicate that the micro-absolute percentage of erosion throughout the study area, with increasing slope, area of erosion and erosion gradually reduce trend increases with the elevation increases, reduced erosion area after, generally good soil and water conservation in the region. Through the analysis of the region with a view to Government decision-making behavior, such as erosion control, soil and water conservation to provide the scientific basis.

Keywords: GIS, great khingan mountains area, soil erosion, USLE

INTRODUCTION

Soil erosion is the main reasons for the degradation of land resources, as a key point of sustainable development, Soil erosion has become the important factor that worsen ecological environment and restrict agricultural production (Liu *et al.*, 2004). Soil erosion research began in the late 19th century, in 1877 the German soil scientist Bwald Wollny related research, observation and qualitative description is limited to surface phenomena (Fernandez *et al.*, 2003). Starting in the 1920s, some scholars begin to quantitative research of soil erosion, in the 60s, the results of such research are also from experience. With the development of the neighboring disciplines, the improvement of test methods and the rise of computer technology, gradually establish a mathematical model of some of the physical simulation of erosion process. In the 80s, with the rapid development of science and technology and computer technology is increasingly perfect, erosion and sediment yield research is developing rapidly, a large number of research results. Especially after the 90s (Mo *et al.*, 2004), the RS and GIS development and extensive application of further research provides a powerful tool for people, model study also began to transition to a distributed by lumped type, scholars at home and abroad a large amount of soil erosion model is put forward. According to the modeling means and

methods of soil erosion model is different, generally can be divided into empirical statistical model and the physical cause model (Ma *et al.*, 2001). Empirical statistical models are mainly from the perspective of erosion factors, through the observation data and statistical techniques, studying on the erosion and rainfall, vegetation, soil, topography, soil and water conservation measures such as the relation between factors. Empirical statistical models abroad to the America universal soil loss equation (Nazzareno and Gianni, 2007) 1978 and revised universal soil equation (Wang *et al.*, 2007) 1997 is typical representative. Physical genesis model based on the physical process of soil erosion, use of hydrology, hydraulics, soil science, the basic principle of river sediment dynamics, as well as other related disciplines, according to the known conditions of rainfall and runoff to describe the process of soil erosion and sediment yield and prediction of soil erosion within a given period of time, but as a result of the calculation is very complicated related research is not much. In addition, earth observation system of "3s" technology in spatial information acquisition, storage, management, update, analysis and application of the three major support technology, is one of the scientific method of soil erosion research towards the quantitative, also more and more widely used in the study of soil erosion.

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This research use the GIS's powerful spatial analysis function to deal with the data of remote sensing image, combined with the basic theory of soil erosion and correction model to analyze the situation of soil erosion with quantitative way at the Great Khingan area in 2011, to determine the intensity level of soil erosion and analyze it comprehensively.

REGIONAL OVERVIEW AND RESEARCH METHOD

This research selects the Great Khingan as the research area, The geographic coordinates of the area is E 121°12'~127°00', N 50°10'~53°33', The area covers 8 km², the forest land of 6.4636 million ha, the living wood growing stock of 5.29 billion m³, the Timber forest stock of 5.29 billion m³ and the forest coverage is 75.16% among the area. The terrain is low-lying West High East and Located in the first step second ladder and its border, with the North-south the Great Khingan as the first ladder, with the west as the second ladder, the altitude range from 300 to 400 m, the terrain is to the northeast toward the southwest and belong to hilly areas, the North, West and Central Highlands's average altitude is 573 m. The Big White of Huzhong District is the main peak of YiLe-HuLi mountain and its Highest Altitude is 1528 m. The lowest altitude of the SanKa township's Yan-Jiang village of the Huma County is 180 m, the climate is cold in winter and warm in summer, there is greater differences in temperature during day and night. Annual mean temperature is -2.8°C, the lowest temperature is -52.3°C, duration of frost-free period is between 90 to 110 days, the mean annual precipitation is 746 mm and belongs to the cold temperate zone continental monsoon climate zone, the type of the regional soil are brown coniferous forest soil, dark brown soil, black earth, meadow soil and swamp soil, etc. The brown coniferous forest soil is the most representative of the Great Khingan's forest soil type. The brown coniferous forest is the main soil type for mountain land, the general thickness of the soil layer is 5-15 cm, The brown coniferous forest is the main soil type for mountain land, the general thickness of the soil layer is 10-20 cm, the river valley plain take the meadow soil and swamp soil as main soil type.

This research mainly takes remote sensing data of the Landsat-TM in 2011 as analyses object, as shown in Table 1.

This research adopts remote sensing data of the Land-sat-TM 2011 as study object. The rainfall data adopt the statistical data that the seventeen Heilongjiang province and the ten Nei Monggol Autonomous Region's weather station of the Great Khingan area has been recorded and we can use the rainfall data to calculate the factor of rainfall erosivity in Soil Loss Equation. The topographic data is acquired

Table 1: Remote sensing data and basic parameters

| Satellite sensor | Photography time | Spatial resolution | Band number | Spectral region/ μm |
|------------------|------------------|--------------------|-------------|--------------------------------|
| TM | 2011 | 28.5 | 6 | 0.45-2.35 |

by using the Spatial Analyst Tools in ArcGIS software to extract terrain factor with the DEM of spatial resolution for 100 m.

RESULTS AND DISCUSSION

On the basis of USLE we can comprehensively analyze that the natural elements influent on the soil erosion, among all the influential factor, there are five factor is most important that are rainfall erosion force factor, soil erodibility factor, terrain factor, vegetation and crop management factor and soil conservation measures factor. The USLE has strong practicability, the general expression (Liu *et al.*, 2004) is:

$$A = R \cdot K \cdot L \cdot S \cdot C \cdot P \quad (1)$$

In the expression, A is soil erosion and express the Annual average erosion of slope sheet erosion and rill erosion per unit area. the unit is ton*ha-1, R is the factor of rainfall erosivity, The unit is MJ*mm*ha-1*h-1, K is soil erodibility factor and express the amounts of soil loss per unit area that form under rainfall erosion force in standard area, the unit is ton*h*MJ-1mm-1, L is slope length factor, S is slope steepness factor, generally we can combine the L and S as LS to consider this issue, C is vegetation and crop management factor; P is soil conservation measures factor.

The factor of rainfall erosivity reflects the potential soil erosivity force on which rainfall acts, in the reference the rainfall erosivity force index of the river basin which Fournie brought forward in 1960 and then The United Nations food and agriculture organization improve it as shown in the function (Mo *et al.*, 2004):

$$F_{\text{mod}} = \sum_{i=1}^{12} P_i^2 / P \quad (2)$$

F_{mod} is the improved Fourier index, P_i is the rainfall in "i" month, P is annual rainfall, if add each improved Fourier index, we find the rainfall erosion force factor R is direct proportional and linear relationship (Fernandez *et al.*, 2003) to it:

$$R = a \cdot F_{\text{mod}} + b \quad (3)$$

R is the factor of rainfall erosivity, F_{mod} is the improved Fourier index, a and b are the decisive constant of climatic zone, on the base of the date which the Institute of Heilongjiang Soil and Water Conservation support, when we calculate the factor of rainfall erosivity R in the Great Khingan mountain area, a = 4.17, b = -152. Using the geographic coordinates

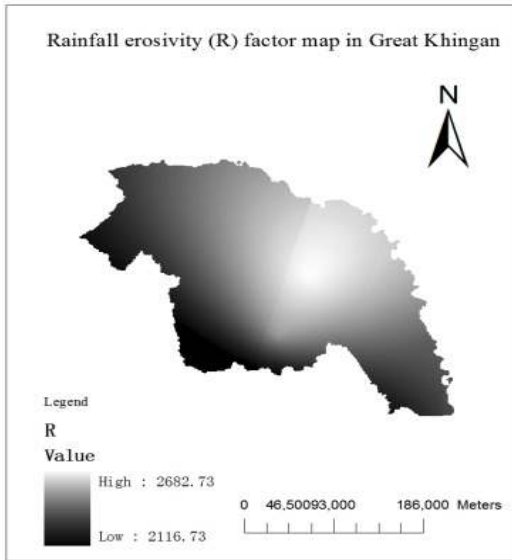


Fig. 1: Rainfall erosivity (R) factor map in Great Khingan in 2011

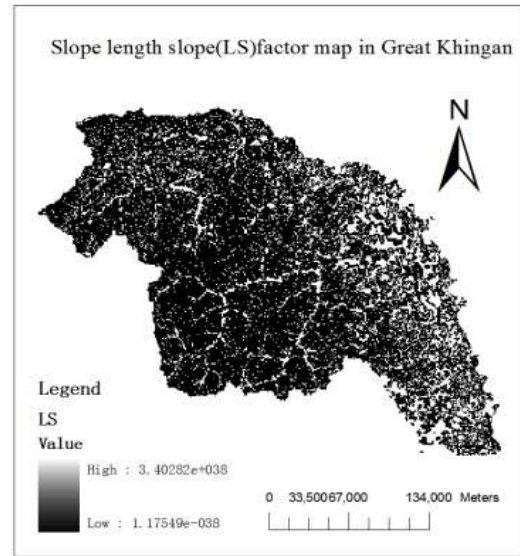


Fig. 3: Slope Length Slope (LS) factor map in Great Khingan in 2011

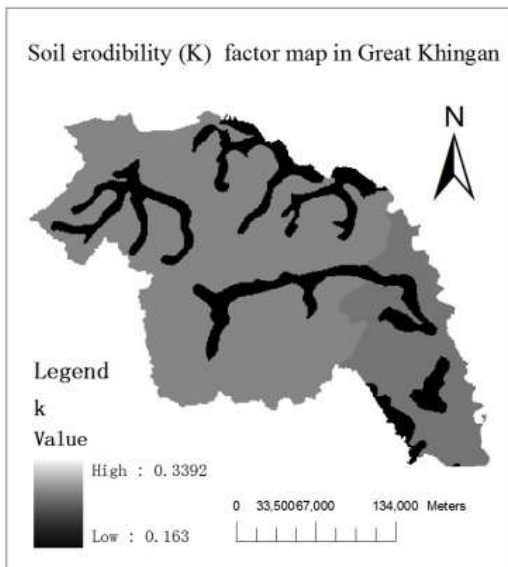


Fig. 2: Soil erodibility (K) factor map in Great Khingan in 2011

Table 2: Values of soil erodibility (K) factor for major soils in Great Khingan

| Soil type | Dark brown soil | Black earth | Meadow soil | Swamp soil |
|---------------|-----------------|-------------|-------------|------------|
| K/ton h/MJ/mm | 0.2524 | 0.26 | 0.3392 | 0.1630 |

with the classified code of soil type in china. The research refer to the study of K value in literature which Xiao-Hui Yang published that the preliminary evaluation of the eastern Great Khinggan forest soil and water conservation function. The value of k is shown as Table 2.

Using the assignment method, we can acquire the spatial distribution map in accordance with the assignment to K in soil type attribute table in Great Khinggan areas, as shown in Fig. 2.

The LS factor also called terrain factor. LS is the ratio between soil loss amounts of Specific slope surface and soil loss amount of standard runoff areas. According to Field observation and experimental plot data, ZhangXianKui etc., established the Ls factor of Heilongjiang soil loss equation (Nazzareno and Gianni, 2007) with regard to the Slope Length and Slope Steepness factor:

$$LS = \left(\frac{\lambda}{20}\right)^{0.18} \left(\frac{\alpha}{8.75}\right)^{1.3} \quad (4)$$

L = The Slope Length

λ = Wavelength (m)

S = Slope Steepness factor

α = Steepness, its type is percentage

According to extract the factor from DEM, the ArcGIS generate rasterized layer of terrain factor, as shown in Fig. 3.

and R we calculate, on the base of the spatial interpolation method, we can generate a series of annual rainfall erosion data to create the format of “Grid”, as shown in Fig. 1.

Soil erodibility is the levels of sensitivity that the soil reacts on the erosion stress separation and the effect of transportation. According to analyze the soil types in Great Khinggan area, the research interpret the remote sensing image, confirm the classified code of four classical (Marques *et al.*, 2007) soil type in Great Khinggan area (dark brown soil is 23, black earth is 24, meadow soil is 35, swamp soil is 37) in according

Table 3: Values of crop and management (C) factor in Great Khingan

| | | | | |
|----------------------|----------|-------------|------------|--|
| The type of land use | Lakes | Paddy field | Dry land | Inter planting of the fruits and cereals |
| C value | 0.000 | 0.180 | 0.310 | 0.100 |
| Forestland | Woodland | Wasteland | Settlement | Economic forest |
| 0.006 | 0.017 | 0.060 | 0.200 | 0.050 |

Table 4: Values of erosion control Practice (P) factor in Great Khingan

| | | | | | | | |
|----------------------|----------|---------------|----------|-----------|----------------------|---------|--------------------|
| The type of land use | Dry land | Timber forest | Woodland | Grassland | Hilly mountain grass | Wetland | Lake and reservoir |
| p-value | 0.35 | 0.1 | 0.2 | 0.2 | 0.2 | 0.1 | 0 |

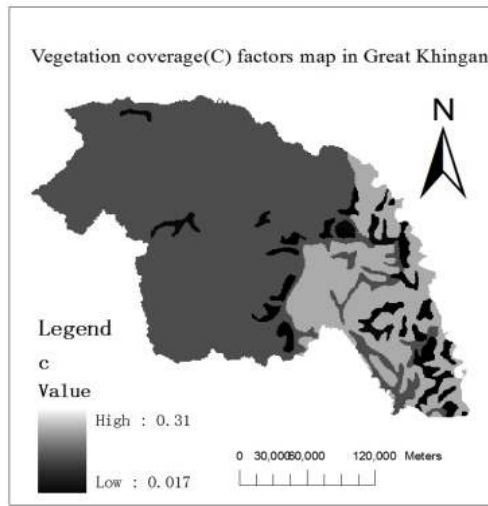


Fig. 4: Vegetation Coverage (C) factors map in Great Khingan in 2011

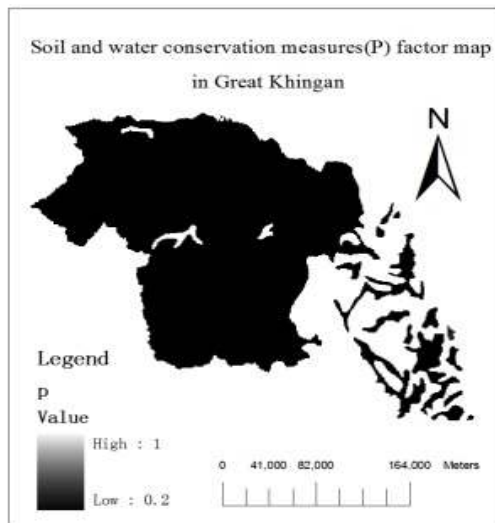


Fig. 5: Soil and water conservation measures (P) factor map in Great Khingan in 2011

The factor C is synthetic effect which the Vegetation coverage and management variables react to the soil erosion.

Domestic scholars analyze the factor C in accordance with the artificial rainfall and part of natural rainfall observations (Wang *et al.*, 2007), according to the relation of the slope sand production calculating and

vegetarian coverage, establish their mathematic relation and finally get the approximate C value, as shown in Table 3, on the basis of the remote sensing images, interpret the type of land use in Great Khingan mountains areas, put the c value into the attribute table of land use type, transform the layers and get the regional C factor map, as shown in Fig. 4.

The water and soil conservation factor P is to describe the ratio between the soil loss amount by special measure and soil loss amount along the slope planting, generally the soil type p value is 1 under no water and soil conservation, in other situations p value range from 0 to 1, P is the most difficulty confirmation factor in ULSE, so we can only estimate the p value (Wang *et al.*, 2008), According to the interpretation of the land use type, the research assign p value, the value of p as shown in Table 4, put the p value into the attribute table of land use type, transform the layers and get the regional P factor map, as shown in Fig. 5.

Results and analysis: Using the ArcGIS software, the research analyzes the spatial distribution graph of each factor in overlay method, gets the pixel average soil erosion graph, analyzes the erosion modulus interval of soil erosion amount is between 0 and 290.609 t/ (km²·a) in Great Khingan mountains areas on the basis of the graph and attribute table, refers to the classification standard of soil erosion intensity that is enact by ministry of water resources, combines the actual distribution characteristics in Great Khingan areas and finally confirms the soil erosion intensity. The analysis show the erosion intensity is mired and slight in Great Khingan areas and the slight erosion takes microscopic scale in contrast with the mired (Guo *et al.*, 2009), as shown is Table 5.

Referring to the classification standard of soil erosion intensity (sl190-96), the soil erosion intensity in study areas is divided into three grades on the basis

Table 5: The classification standard of soil erosion intensity (SL190-96)

| Erosion intensity | Level | Average erosion modulus t/ (km ² ·a) |
|------------------------|-------|---|
| No obvious erosion | 1 | <200 |
| Slightly erosion S I | 2 | 200-800 |
| Slightly erosion S II | 3 | 800-1500 |
| Slightly erosion S III | 4 | 1500-2500 |
| Moderate erosion | 5 | 2500-5000 |
| Intensive erosion | 6 | 5000-8000 |
| High intensive erosion | 7 | >8000 |

Table 6: The classification of soil erosion intensity in Great Khingan

| Grade | Average erosion modulus (t/ (km ² ·a)) | Pixel number | Area/km ² | (%) | Annual erosion amount (t/a) | (%) |
|-------|---|--------------|----------------------|-------|-----------------------------|-------|
| 1 | 0 | 23555 | 23555 | 36.57 | 0 | 0 |
| 2 | 0-200 | 40840 | 40840 | 63.41 | 425480 | 99.36 |
| 3 | 200-290.609 | 12 | 12 | 0.02 | 2740 | 0.64 |

Table 7: Slope soil erosion in the different level in Great Khingan

| Slope grade | Area/km ² | Area/km ² | (%) | Average erosion modulus (t/ (km ² ·a)) |
|-------------|----------------------|----------------------|-------|---|
| 0-5° | 49764 | 244693.81 | 57.54 | 4.91 |
| 5-8° | 10156 | 119752.40 | 28.16 | 11.79 |
| 8-15° | 3906 | 55029.97 | 12.94 | 14.09 |
| 15-25° | 259 | 3116.29 | 0.73 | 12.03 |
| 25-35° | 74 | 671.86 | 0.16 | 9.08 |
| >35° | 256 | 671.86 | 0.47 | 7.86 |

Table 8: The soil erosion amounts of each elevation in Great Khingan

| Elevation/m | Area/hm ² | Erosion amount/t·a ⁻¹ | (%) | Soil erosion modulus (t/ (km ² ·a)) |
|-------------|----------------------|----------------------------------|-------|--|
| 0-200 | 134 | 1097.25 | 0.26 | 8.19 |
| 200-400 | 7214 | 74134.57 | 17.26 | 10.28 |
| 400-600 | 12148 | 118632.02 | 27.63 | 9.77 |
| 600-800 | 12515 | 136401.67 | 31.76 | 10.89 |
| 800-1000 | 7333 | 76567.39 | 17.83 | 10.44 |
| 1000-1200 | 1934 | 21728.92 | 5.06 | 11.24 |
| 1200-1400 | 69 | 846.04 | 0.20 | 12.26 |
| >1400 | 0 | 0 | 0 | 0 |

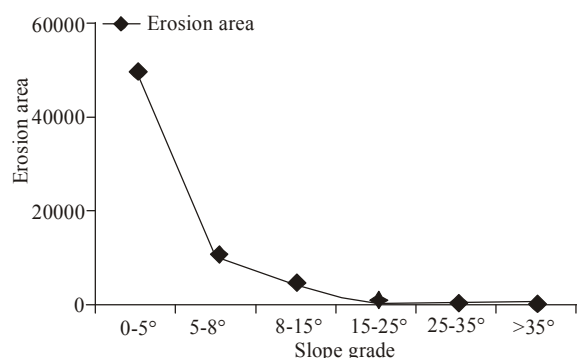


Fig. 6: Different slope soil erosion area level in Great Khingan

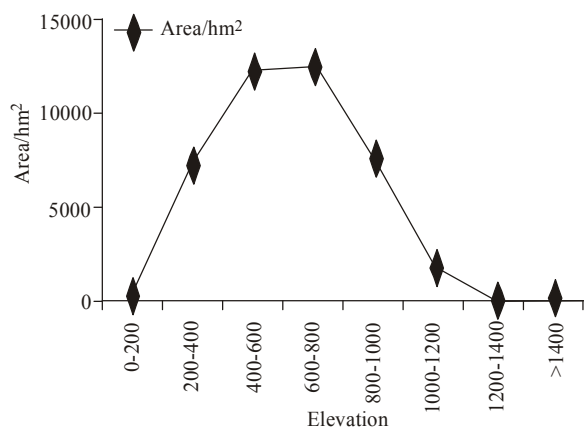


Fig. 7: Different elevation soil erosion area level in Great Khingan

of average erosion modulus; we can acquire the soil erosion intensity distribution map in study areas, calculate the area of each grades, the percentage

account for the total areas and annual erosion amount of each erosion intensity grades, the specific result is as shown in Table 6.

The Table 6 show there are the areas of 40852 km² has been eroded in study areas, account for 63% in total area, the annual erosion amount is 428200 t/a, the mired grade of soil erosion intensity accounts for 63.41% in study total areas and 99.36% in annual erosion amount, the slightly grade of soil erosion intensity accounts for 0.02% in study total areas and the 0.64% in annual total erosion amount. For the further analyses of the relationship of the soil erosion with elevation and slope, sequentially the research analyze the distribution map of soil erosion intensity in Great Khingan areas and DEM in overlay way.

The research superimposed analyze layer of the soil erosion and DEM grid, get the soil erosion amounts of each grade, divide the slope grade into six levels in study areas as: 0-5°, 5-8°, 8-15°, 15-25°, 25-35°, >35° and analyze statistical data, the results is shown in Table 7.

As a result of analysis, the areas of the 0-5° slope grade is 49764 km² in Great Khingan areas, the erosion amount are 244693.81 t/a and account for 57.54% in total erosion amounts, with the increase in slope, the erosion area and erosion amount gradually reduce. According to the analysis of average erosion modulus, the erosion modulus of the 0-5° slope grade are 4.91 t/ (km²·a) and increase with the increase in the slope, when the slope grade is from 8° to 15°, the erosion modulus is maximum, the maximum is 14.09 t/ (km²·a), decrease with the increase of slope grade, the change trend line is shown in Fig. 6.

On the basis of DEM data in study areas, the research use the spatial analysis function of ArcGIS software, get the relative elevation in Great Khingan areas, divide the elevation into eight grades in accordance with 200 m intervals, after the overlay analysis, the results is shown in Table 8.

As a result of analysis, when the elevation is less than 600 m, soil erosion area increase with the increase of the elevation, the elevation is between 600 and 800, the elevation acquire the maximum, the maximum is 12515 km², the elevation is more than 800, the elevation is decrease with the increase of the elevation, as a result of soil erosion amount analysis, when the elevation is between 600 and 800 m, the soil erosion amount is 136401.67 t/a as a maximum, Less than the maximum the elevation increase with the increase of the elevation, more than the maximum decrease.

According to the analysis of average soil erosion modulus, when the elevation is between the interval (0-400, 600-800 and 800-1000 m, respectively), the average soil erosion modulus get the bigger value (10.28, 10.89 and 10.44 t/ (km²·a), respectively), the change trend line is shown in Fig. 7.

CONCLUSION

The erosion intensity is mired and slight in Great Khingan areas, the mired grade of soil erosion intensity accounts for 63.41% in study total areas and 99.36% in annual erosion amount, the slightly grade of soil erosion intensity accounts for 0.02% in study total areas and the 0.64% in annual total erosion amount. Most of the erosion area and erosion amount is within 0-5° slope grade in Great Khingan areas and increase with the increase of the slope, the change tend of the erosion area and erosion amount decrease gradually. In the Great Khingan mountains areas when the elevation of the soil erosion area is during the 600-800 m interval, the area, amount and modulus of the soil erosion is maximum, they increase with the increase of the elevation when less than the maximum and decrease with the increase of the elevation when more than the maximum.

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