

Correlation Analysis of Elevation and the Relief Degree of Land Surface in Henan Province

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Abstract—Elevation and the relief degree of land surface are important factors in describing the regional topographic features. Studying their spatial relationship could further understand the spatial characteristics of the regional topographic distribution. Based on the 30m×30m digital elevation model, this paper uses raster algebra and spatial analysis method to calculate the relief degree of land surface and its correlation coefficient with elevation, analyzes their spatial distribution characteristics from the aspect of structure ratio, in order to explore their spatial relationship. The results indicate that the topography of Henan province is dominated by low and medium altitude elevation and low relief degree. The maximum values of elevation and the relief degrees in longitude lines and latitude lines show 4 ladders, their local differences are significant. The difference of amplitude is obvious in the transition zone around 1 mountain elevation, its variance is obviously higher than that in other mountain transition zones. The elevation of 300m is the separatrix of the correlation coefficient change, on the left the correlation coefficient is directly proportional to elevation, and on the right side which is inversely proportional to elevation. There are clear correlations between the elevations and the relief degrees in 100-1300m and 1500-1800m.

Keywords—digital elevation model; altitude elevation; the relief degree of land surface; correlation coefficient

I. INTRODUCTION

Regional topographic features restrict the redistribution of surface material and energy, directly affect the formation and development of soil and vegetation, determine the advantages and disadvantages of land use and land quality, and have an important impact on the formation of population distribution patterns [1,2,3]. The Relief Degree of Land Surface (RDLS) refers to the contact degree of the altitude difference with the land surface in a given region, as a macro topographic factor in dividing of topography and geomorphology which is an important indicator to describing earth surface morphology. The study of the relief degree of land surface not only has mathematical significance, but also has the significance of soil erosion and geomorphology, has strong accuracy and practical application value in the evaluation of large-scale regional human-land relations. Elevation refers to the vertical distance of a point from the absolute datum plane, is a relative variable to describe the topographic features, which affects the formation and developing processes of soil and vegetation, as well as land use patterns to a large extent [4,5].

In recent years, the researches about elevation and the relief degree of land surface impacts on the land use and

regional economic development have mainly focused on the nature of land use and the spatial characteristics of population distribution, as well as their evolutionary process, have been obtained some valuable results [6-10]. In fact, although there are some correlations between elevation and relief degree in a region, there are certain differences in the distribution characteristics in different elevation ranges. The study of correlation between them in a region is helpful for deeply understanding of regional topography, to provide useful references for the effective use of natural resources.

This paper, based on the 30m×30m digital elevation model (DEM), utilizes raster algebra and spatial analysis method to calculate the relief degree of land surface and its correlation coefficient with elevation, and analyzes their spatial distribution characteristics from the aspect of structure ratio, explores their spatial relationship, in order to provide useful references for deeply understanding Henan topography.

II. DATA AND RESEARCH METHODS

A. Research Area Overview and Data

Henan Province (31°23'N-36°22'N, 110°21'E-116°39'E) is located in the transition zone of China's terrain from the second to the third ladder, with the total area of 167 thousand km². The three sides as the north, west and south are semi-circular surrounded by Taihang, Funiu and Tabie mountains [9]. The central and east regions are Huanghuaihai alluvial plain. 30m×30m DEM used in the study is provided by Computer Network Information Center (<http://www.gscloud.cn>).

B. Research Methods

The relief degree of land surface is an important index to describe the topographic features of a region, refers to the contact degree of the altitude difference with the land surface in a given region, defined as

$$RDLS = ALT / 1000 + [Max(H) - Min(H)] \times [1 - P(A) / A] / 500 \quad (1)$$

where ALT is the average elevation within the ε neighborhood of the analysis unit, $Max(H) - Min(H)$ is the altitude difference in the neighborhood, $P(A)$ and A respectively are the surface area and the project area of the neighborhood. 500m is a reference mountain height in China. As an independent value, the geographical significance of RDLS indicates that $RDLS \geq 1$ means the regional topography amplitude is in $int(RDLS)$

reference mountains, $RDL < 1$ means the regional topography amplitude is below 1 reference mountain[5,6,9,11,12,].

Correlation coefficient is used to reflect the correlation degree between variables, by the sum of multiplied the dispersions of two variables. Suppose $(x_i, y_i), i = 1, 2, 3 \dots n$ is the observations of two-dimensional random variable (X, Y) , and $\bar{x}, \bar{y}, D(X)$ and $D(Y)$ respectively are the mean and variance of X and Y , the correlation coefficient of X and Y is defined as [14]

$$\rho = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{D(X)D(Y)}} \quad (2)$$

ρ belongs to $[0,1]$, the greater ρ means strong correlation, as $\rho = 1$ means X and Y is linearly dependence, $\rho = 0$ means X and Y mutual independence[13,14].

III. CORRELATION ANALYSIS OF ELEVATION AND THE RELIEF DEGREE OF LAND SURFACE IN HENAN PROVINCE

A. Distribution Characteristics of Elevation

Figure 1a is the elevation distribution in Henan Province, Figure 1b is the 45°side view of the elevation distribution from the south focusing on the centroid, In order to show the elevation difference, the z-value is magnified by 20 times. The elevation of the province (WGS84 ellipsoidal plane) is between 23.2m and 2413.8m with an average elevation of 403m. The province is dominated by medium and low elevations, the area of 180-500m is about 128.4 thousand km², occupies 90% of the total area, the area below 180m accounts for 0.6% mainly distributed in the south and east part of the province, the region with the elevation between 500m and 1500m is the theme of the province mountain, with the area about 34.8 thousand km², while the area above 1500m is only 2 thousand km² (Figure 1c and Figure 1d).

Figure 1e is the curve of elevation statistics versus longitude, the maximum of elevation obviously shows 4 ladders from the west to the east. they respectively are the high altitude region located in the west of 112°24'36"E with the average maximum elevation about 1971m, and 38.4 thousand km², the middle-high altitude region located between 112°24'36"E and 113°48'48"E with an average maximum elevation of 1427m, and 43.4 thousand km², the middle-low altitude region at 113°48'48"E to 115°55'12"E with the average maximum elevation of 849m, and 80.9 thousand km², and the low altitude region in the east of 115°55'12"E with the average maximum elevation of 244m, and 4.3 thousand km² (Figure 1c). The mean of the elevation decreases gradually with the increase of longitude, and the minimum value presents 2 ladders with the west-high east-low with 110°58'48"E as the dividing line, and the western region average is 453m, accounting for 2.49% of the total area, the average value of the eastern region is 178.61m, accounting for 97.51% of the total area.

Figure 1f is the 45°side view of the elevation distribution from the west focusing on the centroid(20 times z value), Figure 1g is the curve of elevation statistics versus latitude. the maximum of elevation obviously shows 4 ladders from the south to the north. They respectively are the low altitude region located in the south of 33°14'24"N with the average maximum elevation about 872m, the high altitude region located between 33°14'24"N and 34°30'36"N with an average maximum elevation of 1928m, the middle-low altitude region at 34°30'36"N to 35°07'12"N with the average maximum elevation of 1274m, and the middle-high altitude region in the north of 35°07'12"N with the average maximum elevation of 1532m, their area respectively account for 31.36%, 41.28%, 14.77% and 12.59% of the province area (Figure 1g). The mean value shows 2 parabola characteristics connecting at 33° 39'36" N. The minimum value is basically keeping at 132m except for the north and south edges.

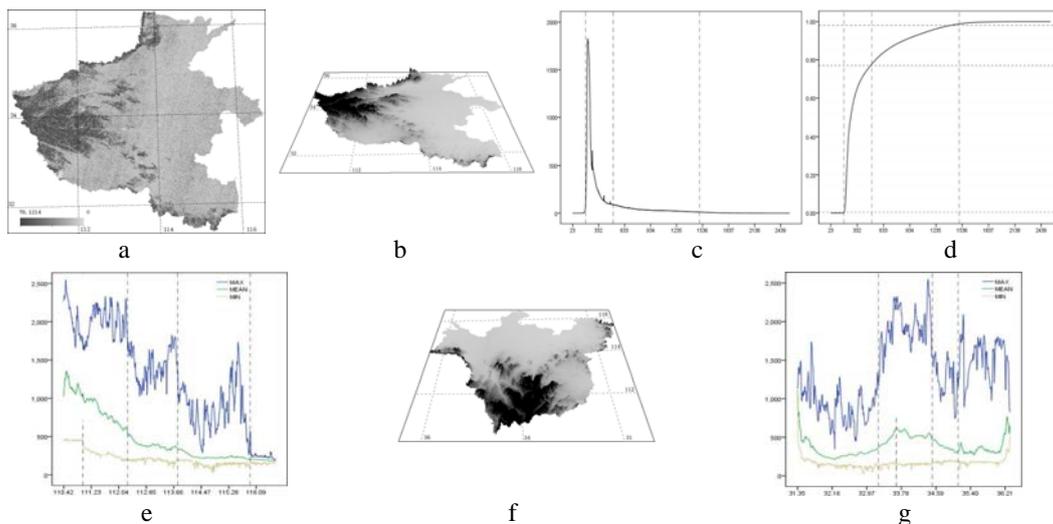


FIGURE 1. THE DISTRIBUTION CHARACTERISTICS OF ELEVATION IN HENAN PROVINCE

B. Distribution Characteristics of the Relief Degree of Land Surface

Using Eq.1 and setting $\varepsilon=1km$, to calculate the relief degree of land surface in Henan province, the results are showed in Figure 2, Figure 2a and Figure 2b respectively are 45°side views of the relief degree of land surface from the south and west focusing on centroid, in order to show the variation, the relief degree of land surface is magnified by 10 thousand times. The relief degree of land surface in Henan Province is between 0.05-4.77. From the distribution density(Figure 2c) and area distribution (Figure 2d), it is dominated by low values, the area under 0.5 is 75.06% of the total area, with it increase, the area in the same dimension interval, the percentages decrease gradually, respectively are 0.5-2.5, 12.02%, 6.59%, 3.61%, 1.79%, as greater than 2.5 the area only accounts for 0.93%.

Figure 2e and 2f respectively are the curve of the relief degree of land surface statistics versus longitude and altitude. Overall, there are great similarities between the change of elevation and the relief degree of land surface along longitude and latitude. On the longitude, the average maximum values in the 4 ladders respectively are 3.73, 3.33, 1.99 and 0.41 with areas about 36.90, 43.80, 81.70 and 4.60 thousand km². On the latitude, the average maximum values in the 4 ladders respectively are 1.95, 3.60, 2.56 and 3.45 with areas about 52.4, 68.90, 26.10 and 19.60 thousand km². Considering the characteristics of elevation distribution along longitude and latitude, there is a significant difference between the their changes around dividing lines, existing a significant correlation between them.

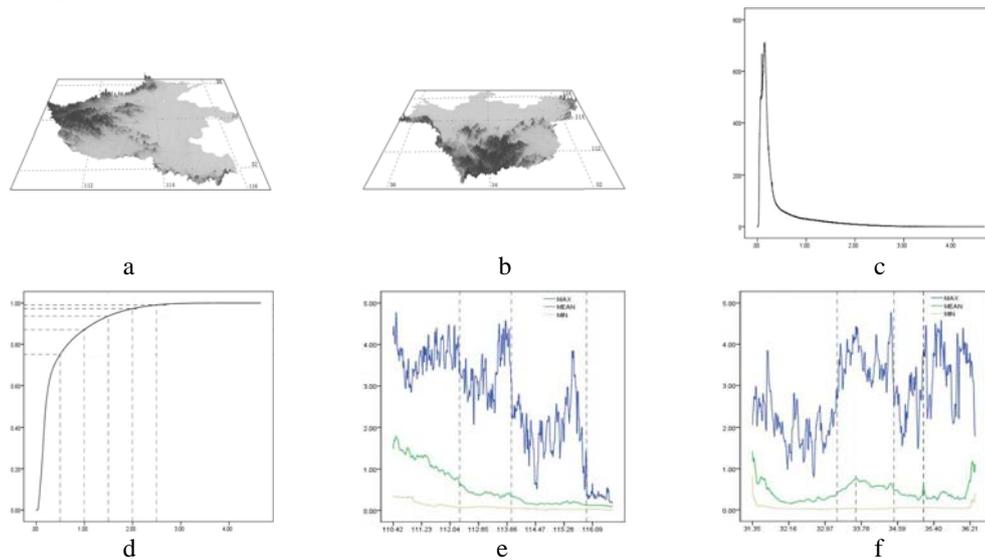


FIGURE II. THE DISTRIBUTION CHARACTERISTICS OF THE RELIEF DEGREE OF LAND SURFACE IN HENAN PROVINCE

TABLE I. THE STATISTICS CHARACTERISTICS OF ELEVATION AND THE RELIEF DEGREE OF LAND SURFACE

Class	1	2	3	4	5	6	7	8	9	10	11	12	13
EM	0.84	1.94	2.33	3.43	4.48	5.48	6.49	7.48	8.49	9.49	10.50	11.49	12.49
ESD	16.71	22.27	26.37	28.59	29.00	28.72	28.99	28.74	28.81	28.94	28.92	28.74	28.85
HM	0.35	0.13	0.16	0.34	0.55	0.70	0.87	1.02	1.18	1.34	1.47	1.59	1.72
HSD	0.23	0.07	0.08	0.17	0.26	0.31	0.36	0.40	0.44	0.47	0.49	0.50	0.52
CC%	0.12	20.11	25.35	21.34	17.38	14.82	12.14	11.86	9.23	9.46	6.67	7.32	6.89
Class	14	15	16	17	18	19	20	21	22	23	24	25	
EM	13.48	14.48	15.47	16.46	17.45	18.46	19.46	20.45	21.43	22.42	23.41	24.42	
ESD	28.81	28.75	28.65	28.61	28.65	28.70	28.59	28.39	27.99	28.10	28.67	28.10	
HM	1.83	1.94	2.06	2.18	2.32	2.45	2.54	2.64	2.73	2.81	2.92	2.96	
HSD	0.52	0.53	0.55	0.58	0.60	0.62	0.62	0.62	0.62	0.62	0.59	0.57	
CC%	6.20	5.54	6.66	6.63	6.86	4.72	3.68	4.59	4.29	3.26	3.50	3.21	

C. Correlation Analysis of Elevation and the Relief Degree of Land Surface

In order to study the relationship between elevation and the relief degree of land surface, according to the characteristics of elevation distribution in the province, this study divides the elevations into 25 classes with interval of 100m, and the i^{th} class includes the elevation belongs to $[100(i-1), 100i)$ (Figure 3a). According to Eq.2 by using the partition statistics and map algebra calculate the correlation coefficient of elevation and the relief degree of land surface, the results shown in Table 1.

The elevation means on the elevation series show the characteristics of linear increase, its linear regression equation is $EM = 0.992CLASS - 0.397$ ($R^2 = 0.286$), the linear regression equation after range standardization is $EM = 0.042070CLASS - 0.05246$, indicating that the elevation classification is relatively reasonable. However, as the average elevation increases, the standard deviation of elevation gradually increases, reaching a local maximum of 28.59 in the elevation 400m, and oscillating around 28.65 in the region above 400m, indicating that relief amplitude in the low altitude region is relatively small. the difference of relief amplitude is obvious in the transition zone around 1 mountain elevation, its variance is obviously higher than that in other mountain transition zones(Figure 3b).

With the elevation increases from 23 to 200m, the mean value of the relief degree of land surface decreases, and the mean value in 200-300m basically remains at a relatively low level of 0.016, above 300m, it shows some linear increasing characteristics, its linear regression equation after range standardization is $EM = 0.041892CLASS - 0.10608$ ($R^2 = 0.134$), the relative gradient is obviously less than it of the average elevation. As the elevation increases from 23 to 200m, the standard deviation of the relief degree of land surface is gradually decreasing, it keeping at a lower level about 0.08 in 200-30m, and then increasing. Comparing with the elevation variation, its variations has a clear increasing trend. all of them show that with the elevation increasing, the relief amplitude in the same elevation zone becomes more obvious (Figure 3b).

With the elevation increases to 300m, the correlation coefficient between elevation and the relief degree of land surface increases, reaching a local maximum value of 0.2535 on 300m, and then gradually decreasing to 0.0321 on 2500m. The decreasing rate in 300-400m is obviously higher than that in other intervals, the absolute change rate in 23-100m is obviously highest. the correlation coefficients in the intervals of 100-1300m and 1500-1800m is higher than the relevant critical value of 6.25%[9], there is a clear correlation between elevation and the relief degree of land surface in these regions (Figure 3c).

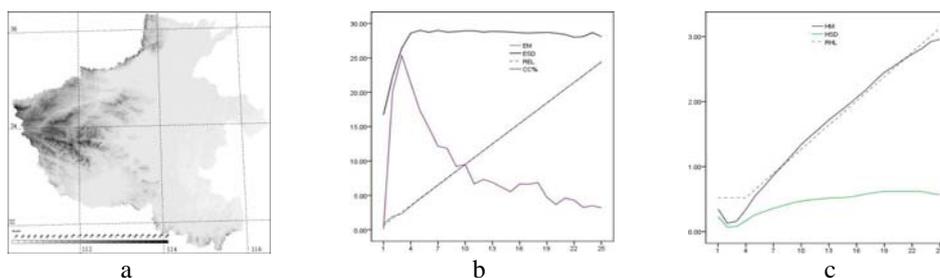


FIGURE III. THE DISTRIBUTION CHARACTERISTICS OF ELEVATION AND THE RELIEF IN HENAN PROVINCE

IV. CONCLUSION

Based on the digital elevation model, the paper utilizes spatial analysis method and raster algebra to calculate the relief degree of land surface and its correlation coefficient with elevation, and analyzes the spatial distribution characteristics of elevation and the relief degree of land surface, studies their spatial correlations. The results show that:

(1) The topography of Henan province is dominated by low and medium altitude elevations, with the longitude increasing, the elevation maximum obviously shows 4 ladders, the elevation mean and elevation minimum gradually decreases. with the latitude increasing, the elevation maximum also shows 4 ladders, the elevation mean shows two connecting parabola characteristics.

(2) The topography of Henan province is dominated by low relief degree, its curves versus longitude and latitude is have great similarities with that of elevation, there is a significant difference between their changes around dividing lines, existing a significant correlation between them. The

difference of relief amplitude is obvious in the transition zone around 1 mountain elevation, its variance is obviously higher than that in other mountain transition zones.

(3) The elevation of 300m is the separatrix of the correlation coefficient change, on the left with the increase of the elevation, the correlation coefficient between elevation and the relief degree increases, and on the right side which gradually decreases with the increase of elevation. There are clear correlations between the elevations and the relief degrees in 100-1300m and 1500- 1800m.

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