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APPLICATION OF DIGITAL IMAGE ENHANCEMENT PROCESSING OF LANDSAT DATA FOR TERRAIN MAPPING OF SOUTHERN HUAIROU COUNTY OF BEIJING (PEKING), CHINA

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ABSTRACT

This paper deals with the application of digital image processing of Landsat images of Beijing, China.

It was found that different enhancement techniques have very varied value for the terrain mapping. Following a comparison of several methods an edge enhanced image was found to give the best result. This image was digitally enlarged to a scale of about 1:100,000 and was used for terrain mapping. As a result, five land systems and a number of compound land facets were recognized.

A comparison was made between the terrain map derived from digital Landsat image processing and the existing terrain map based on black and white aerial photographs and large scale topographic maps. The advantages and the limitations of digital image processing the terrain mapping compared with the conventional approach are presented.

I INTRODUCTION

Terrain evaluation or land evaluation is the assessment of man's possible use of land for such purposes as agriculture, forestry, engineering and recreation (Stewart, 1968). Terrain mapping is the most significant and fundamental work for terrain evaluation.

Conventional terrain mapping, especially in developing countries, is mainly dependent on visual interpretation of black and white photographs and use of large scale topographic maps along with field survey. Data derived from satellite -some sensors has been mainly applied in reconnaissance terrain surveys at scales from 1:250,000 - 1:1,000,000, with land systems being used as the basic mapping unit, as in the land evaluation of Jordan (Mitchell, 1978) and of arid and semi-arid regions (Mitchell, 1981). However, digital image processing has been little used in deriving products for comprehensive or integrated terrain mapping compared with its extensive use in land use and land cover mapping although these newer methods of data handling, processing and classification have offered a substantial opportunity to those concerned with terrain resources evaluation (Townshend, 1981). It is worthy of mention that conventional land system mapping units in Queensland could be matched with digitally classified spectral classes or acceptably homogeneous combinations of several spectral classes on Landsat imagery (Robinove, 1979).

The objectives of the study in this paper are firstly to examine the value of digital Landsat imagery processing for terrain mapping not only of land systems but also of land facets, and secondly to derive a relatively inexpensive, time-saving and effective approach of terrain mapping at medium or large scales.

II STUDY AREA

A study area encompassing approximately 250 square kilometres in southern Huairou County of Beijing, China was selected (Figure 1).

Topographically, the land surface dips gently from 700-800 metres above sea level in the northwest to 70-100 metres in the southeast. In the northwestern and central parts of the area there are accidented mountains consisting of Sinian (Pre-Cambrian) limestone with flint bands and dolomitic limestone (Figure 2). Between them are rolling mountains and hills of Mesozoic granite, and flat bottomed and wide river basins covered by Tertiary or Quaternary sediments. In the southeast there are Tertiary diluvial fans and eroded residual hills of Jurassic volcanistic rock and andesites.

A terrain map of this area was produced at a scale of 1:100,000, based on black and white aerial photographs at a scale of 1:18,000, topographic maps at 1:50,000, geological maps at 1:100,000 and Evidence field survey which involved 10 man-months effort. The approach adopted was similar to the integrative hierarchical land systems approach described by Stewart (1968).

III METHODS

A computer-compatible magnetic tape of cloud-free Landsat imagery collected on September 10, 1978 and obtained from the EROS Data Centre was used for the study. The digital enhancement processing of the tape including contrast stretching, edge enhancement, band ratioing, principal component analysis, density slicing and false colour compositing of the original or processed images were conducted mainly on the Cromemco micro-computer based system in the Remote Sensing Laboratory of the Department of Geography, the University of Reading, and partly on the GEMS system in the Remote Sensing Centre of RAE, UK.

A sub-scene of the study area was digitally enlarged to a scale of about 1:100,000 and hardcopy enlargements were generated. These were visually interpreted to make a geomorphological map. The mapping units consisted of two levels which corresponded approximately to land systems and land facets, respectively. Five land systems and a number of land facets were then defined by superimposing the geomorphological map on a lithological map of the same area in conjunction with the recognition of the colours and the patterns related to the terrain units on the enlarged images. Finally, a comparison between this terrain map and the existing one was carried out to assess the advantages and limitations of digital image enhancement for terrain mapping.

IV RESULTS

Numerous studies have shown that image enhancement is an efficient tool for improving the interpretability of an image not only of Landsat data, but also of virtually any digital image data (Lillesand and Kiefer, 1979, Sabins 1978, Townshend 1981). The present study revealed that different enhancement techniques have varied values for terrain mapping in the study area.

Digital contrast stretching is the most commonly applied image enhancement process (Sabins, 1978). In this study the different contrast stretching approaches including linear contrast stretching, histogram-equation and histogram-Gaussian contrast stretching were examined. It was found that the linear contrast stretching gave the best contrast enhancement as shown by the histograms (Figure 3), for the present purpose of terrain mapping.

In addition, the study also showed that the edge enhancement obtained using a digital filter of 3 by 3 pixels are very useful for emphasizing the subtle variations of the ground features, in particular those in the mountains and the hills. On the false colour composite of the edge enhanced images of bands 4, 5 and 7 (Figure 4) the large gullies can be much more clearly recognized. Other features such as towns and large villages also can be easily identified. On the relatively low and flat diluvial fans the relief and the significant features such as residential areas, the railway and the canal can be detected. Also, the crops in the river basins and on the diluvial fans can be observed based on their high reflection in the near infrared.

Band ratioing such as bands 7/5 and 7/4 did not offer much assistance for terrain mapping because it greatly reduced the effects of relief. However, it had the advantage of enhancing the appearance of rivers and their tributaries, reservoirs, as well as towns and large villages although the relief shadows were not eliminated. On the band ratioed scenes of 7/5 or 7/4, in particular 7-5/7+5, the vegetation which is mainly concentrated on the solar shadowed slopes in the mountain areas was readily identified.

Principal component analysis has been found useful in a maximizing relief impression (Donker and Meijerink, 1977). However, in this study the resultant principal component analysis did not yield images with relief enhancement. Also, density slicing was of little use for the recognition of the terrain units. In contrast multiplying such bands as 5 and 7 increased the relief to a certain degree in comparison with the original scenes.

The comparison between the terrain map derived from Landsat images (Figure 5) and the existing one (Figure 6) shows that the outlines of the terrain units on these two maps are approximately comparable although the details of their boundaries are somewhat different due to firstly differences in their geometric projections. These differences arise primarily due to unresampled images being used so that the scene is apparently stretched in the x - direction along the scan lines. Secondly differences in the boundary stem from the different classificatory procedure used to produce the two maps. The previously published terrain map is based on the conventional land systems approach relying heavily on air photographs and existing maps as described in the second section. The new map which was generated relied primarily on interpretation of the Landsat image which displays mainly relief and land cover. However, it is obvious that the outlines of some ground features such as towns and large villages are more clear on the new terrain map than on the existing one. Some other features such as Ganjianyu Reservoir can be identified on the new terrain map whereas they are missed on the existing map because the Landsat images are more up to date than the topographic maps and the aerial photographs on which the existing terrain map was compiled.

It should be noted that the Great Wall appears on the new terrain map which was recognized based on its circuitous linear feature along the mountain ridges on the edge enhanced image although its width is smaller than the resolution of the Landsat pixel.

So far as the distribution of the vegetation the existing terrain map shows an advantage over the new terrain map because the terrain units of the hills (No. 21 - 22) and the mountains (No. 23 - 28) were distinguished not only by the lithological and the geomorphological features, but also the vegetation types. Knowledge about the distribution of the vegetation in this area came from mostly an extrapolation on the basis of the field survey and reference to existing published information, and interpretation of aerial photographs. In contrast, the vegetation, in particularly the agricultural crops and the fruit plants both on the diluvial fans and in the river basins are easily recognised on the enhanced images based on the characteristic colours. This will be discussed in another paper.

The biggest problem of the new terrain map resulted from the relatively low resolution of the Landsat pixels. Therefore, the land facets cannot be totally separated from each other. For example, even the gullies and their tributaries in the mountains and the hills were clearly illustrated on the existing terrain map while only the larger gullies were shown on the new terrain map. Similarly, the terraces and the flood plains in the river valleys were usually distinguished on the existing terrain map whereas on the terrain map derived from Landsat data they merged into the compound land facets, i.e. combinations of simple land facets based on close relationship or even on mapping convenience which correspond approximately *sub-urochischa* of 'associations of facies related to a single slope' in the Soviet Union (Vinogradov et al., 1962).

V CONCLUSIONS

Digital Landsat image processing is an effective tool in terrain mapping compared with the conventional approach based on black and white aerial photographs and large scale topographic maps. However, different digital image processing techniques have unequal values in the terrain mapping. It was found that even using only relatively simple image enhancement techniques such as linear contrast stretching, edge enhancement and false colour compositing terrain mapping at the levels of land system and compound land facet in an area of low vegetation cover and good quality imagery can be achieved with less labour and probably at lower cost compared with the conventional approach relying on aerial photographs and ancillery maps. This has great importance in particular for developing countries.

For more detailed mapping of individual land facets the digitally enhanced landsat images were less successful; since many of the facets could not be distinguished. It is believed that the situation will be significantly improved by using data taken from high resolution sensors such as the Thematic Mapper of Landsats 4 and 5. The prospect of using digital Landsat image processing for terrain mapping is optimistic because Landsat images can provide a synoptic view over a study area and a repetitive covering upon which seasonal and longer term changes can be observed.

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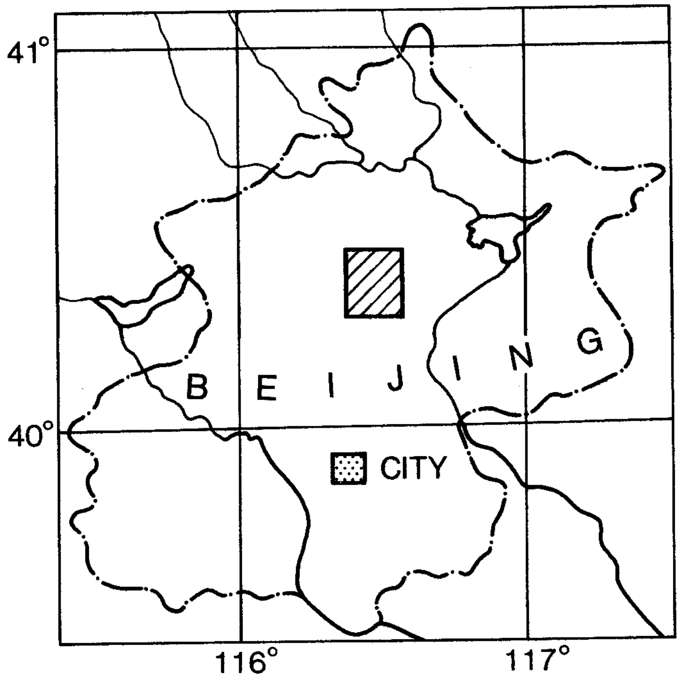


Figure 1. The location of the study area in Beijing of China

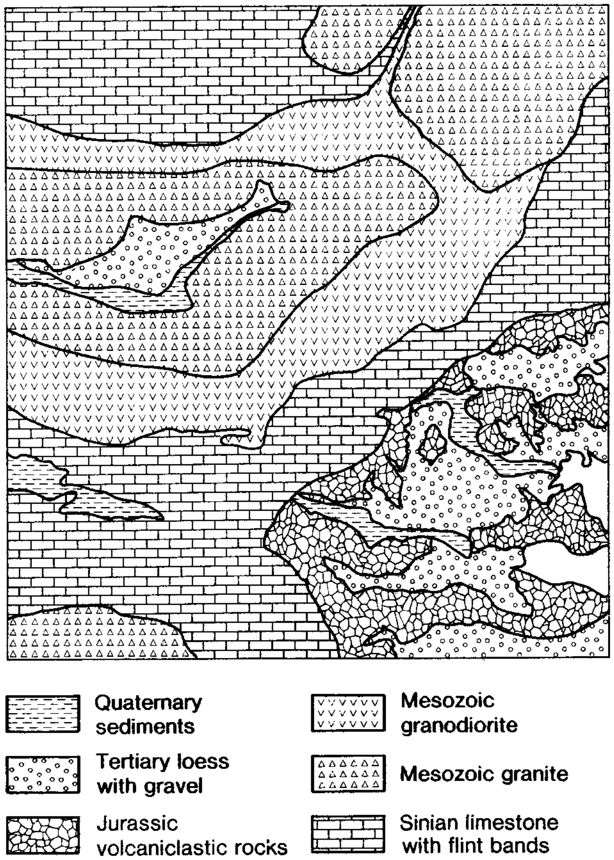
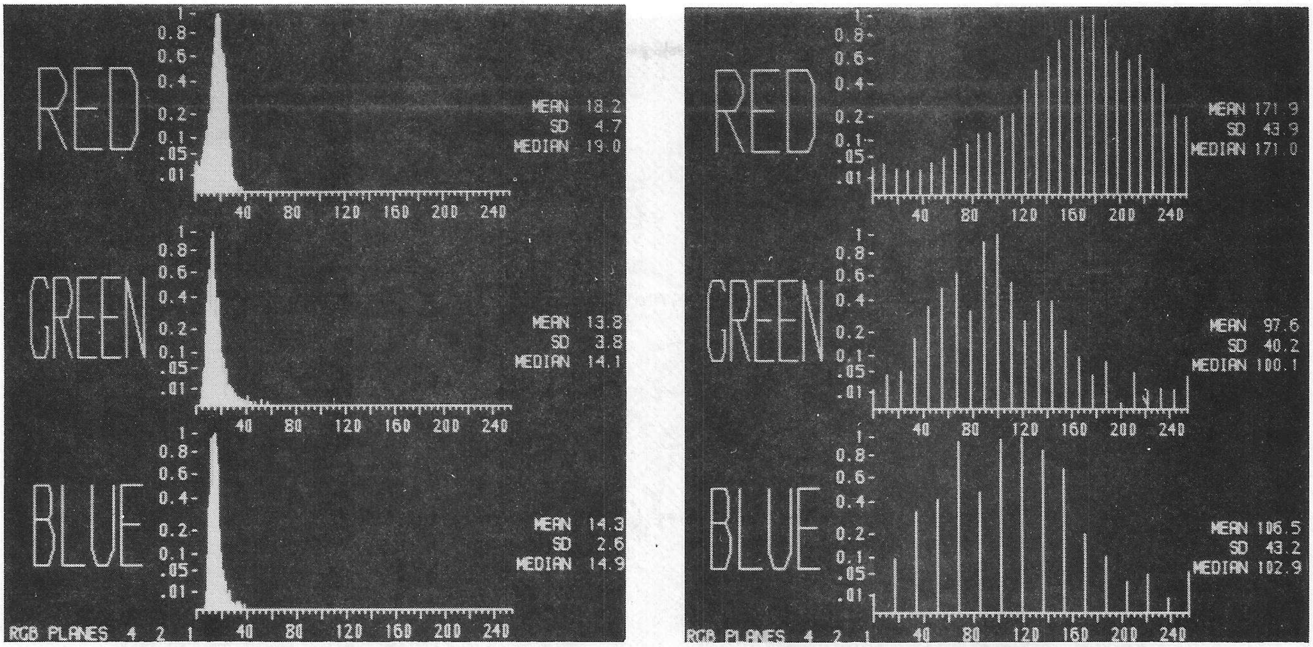


Figure 2. The lithological map of the study area.



Before contrast stretching

After linear contrast stretching

Figure 3. The histograms show the significantly improved contrast after the linear contrast stretching of bands 4 (red), 5 (green) and 7 (blue) of the study area.

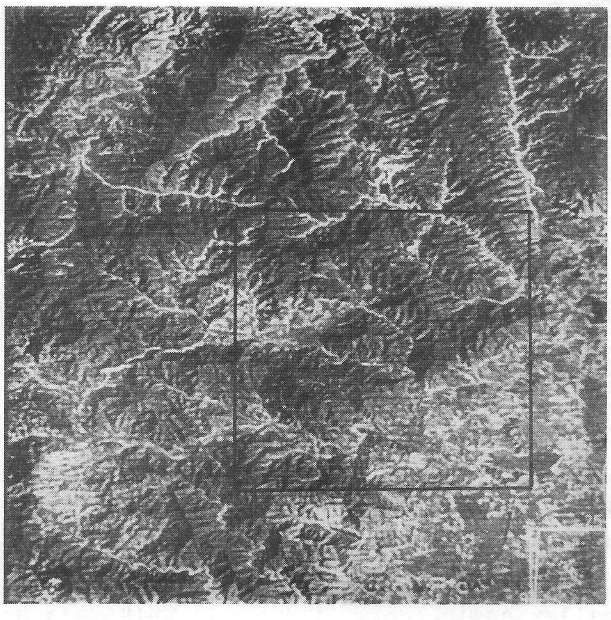


Figure 4. The false colour composite of edge enhanced images of bands 4, 5 and 7 after linear contrast stretching (The original image is in colour). Location of the study area lies within quadrat.

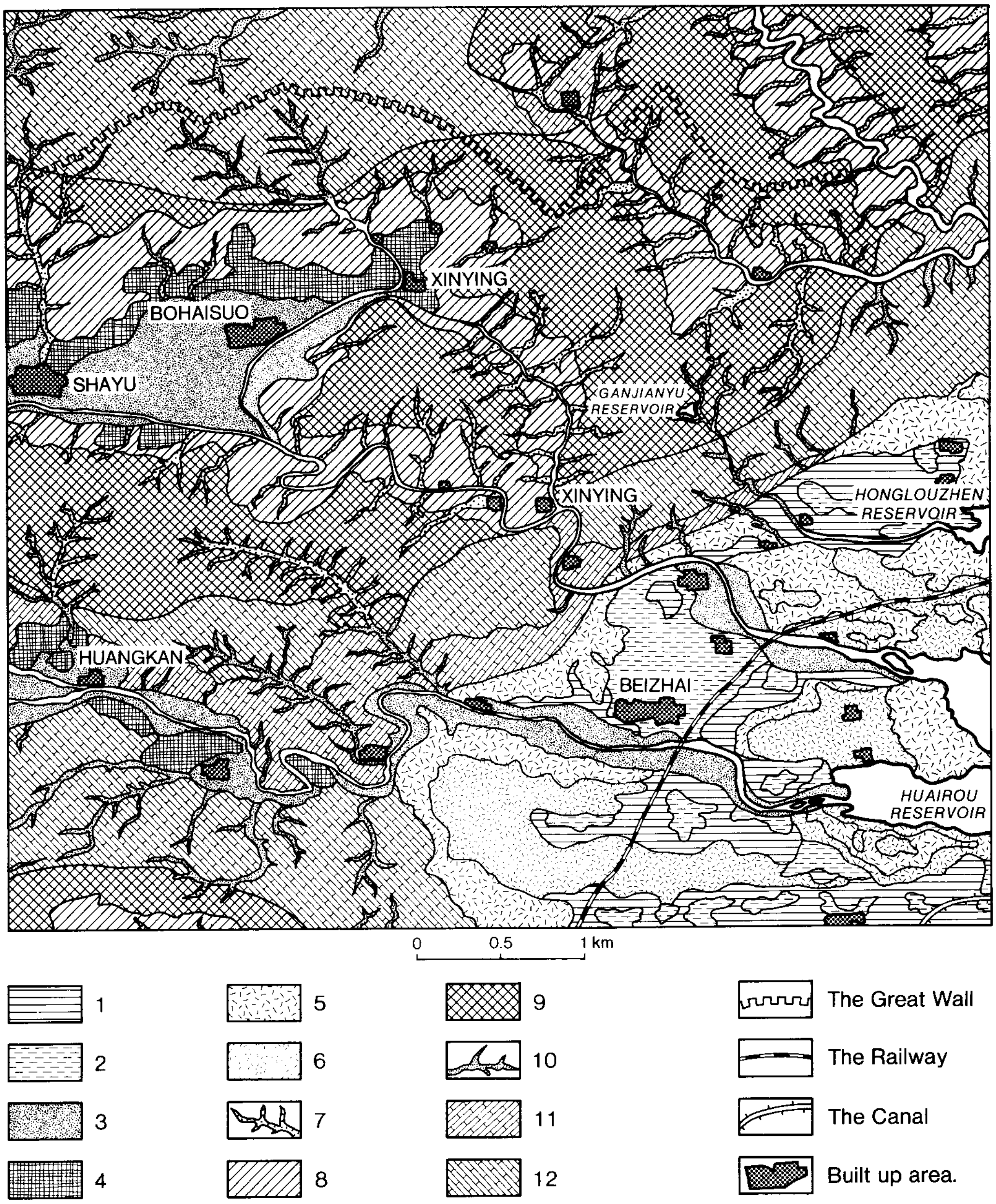


Figure 5. The terrain map of the study area based on digital Landsat image enhancement.

Legend

I Diluvial platform
1 High diluvial platform
2 Lowland between diluvial platforms

II River valley basin
3 River terrace and alluvial flat
4 Eroded platform adjacent to river valley basin

III Volcanic foothill
5 High volcanic foothill
6 Low volcanic foothill

IV Granite mountain
7 River valley and gully
8 Granite hill adjacent to river valley
9 Granite mountain

V Carbonate mountain
10 River valley and gully
11 Carbonate hill adjacent to river valley
12 Carbonate mountain

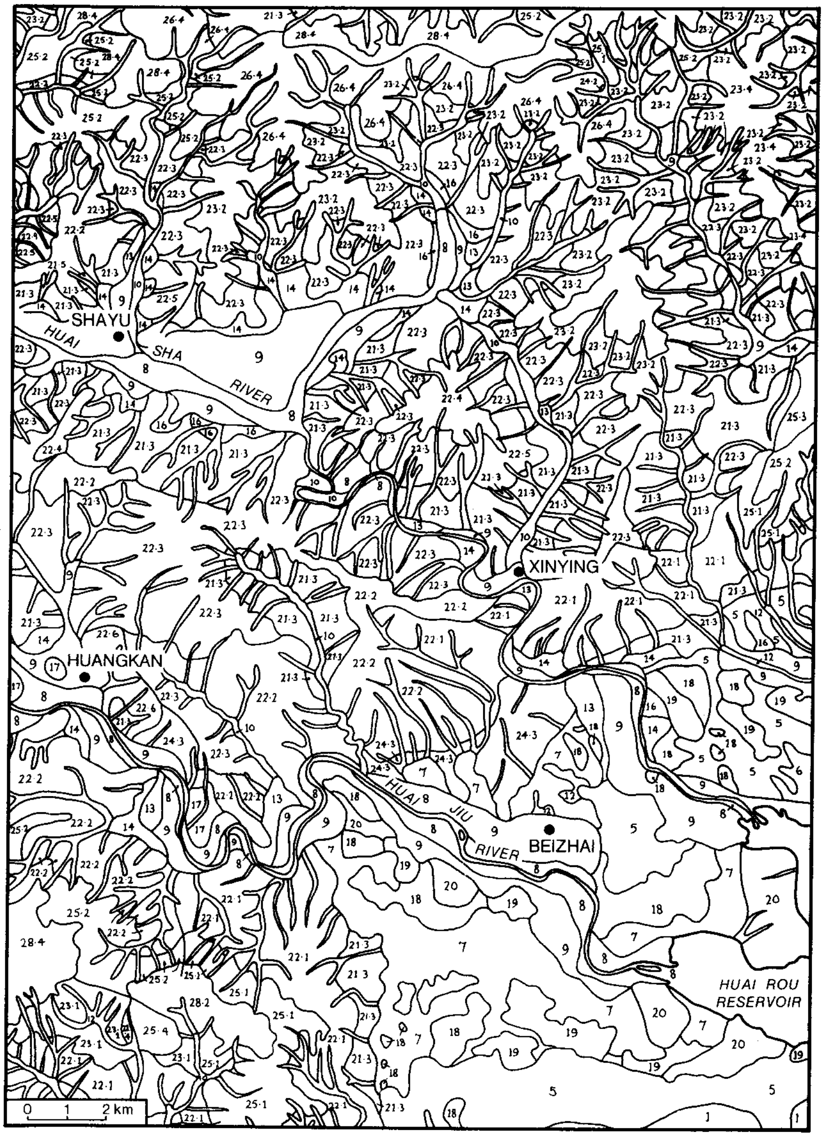


Figure 6. The terrain map of the study area based on black and white aerial photographs and topographic maps 1:50,000 (After: Chen Zhun Kang et al., 1981. The author participated in the survey and mapping).

Ledgend

Alluvial plain
1. Gently sloping flat
2. Slightly undulating sandy flat*
3. Shallow depression*
4. Water-logging depression*

Foothill eroded platform
5. Diluvial platform
6. Lowland between diluvial platforms
7. Diluvial platform between hills

River valley and gully
8. Flood plain
9. Alluvial terrace
10. Gully covered by soil
11. Gully covered by gravel
12. Gully covered by loess

Platform adjacent to river valley
13. Alluvial platform
14. Diluvial fan platform
15. Platform covered by loess
16. Platform covered by thick soil
17. Platform covered by thin soil

Foothill
18. Very low and rounded hill
19. Low hill
20. High hill

Eroded hill adjacent to river valley
21. Hill covered by soil
22. Eroded hill

Low mountain with shrub and grass near river valley
23. Low mountain of acidic rock
24. Low mountain of volcanic rock
25. Low mountain of limestone

Low mountain with shrub and forest far from river valley

26. Low mountain of acidic rock
27. Low mountain of volcanic rock
28. Low mountain of limestone

Vegetation

1. Grass
2. Shrub
3. Fruit plants and crops
4. Oak forest
5. Pine forest
6. Juniper forest

* not presented in the mapped area.