Slope landscape change in a simulated watershed

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Abstract — **An artificial loess watershed is adopted to investigate the variation in slope landscape structure with loess watershed evolution. The evolution of the simulated loess watershed was driven by the exogenetic force of artificial rainfall. Quantitative indices of the slope landscape structure varied regularly following the evolution of the simulated loess watershed. Mean patch area (AREA_MN), and Patch Cohesion Index (COHESION) kept increasing following the evolution of the simulated watershed, while Perimeter-Area Fractal Dimension (PAFRAC), and Interspersion and Juxtaposition Index (IJI) showed an opposite trend. All the indices change actively in the early and active development periods, but changed slowly in the stable development periods.**

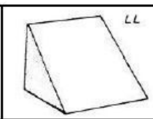
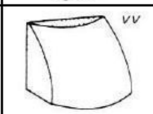
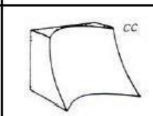
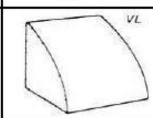
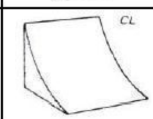
I. INTRODUCTION

Quantificational analysis of loess terrain is a key subject in the research of the loess plateau [1-7]. Tang et al (2008) proposed slope spectrum to quantitatively describe loess landforms [8], Zhou et al (2010) discussed the spatial pattern of loess landform based on loess positive and negative terrain [9]. However, their research cannot properly describe the spatial structure of loess slopes. In this paper, we investigate loess landforms from the landscape ecology point of view. Firstly, we classified slope into six types as table 1. Then, each map-patch of slope type was taken as an independent functional patch from the view point of landscape. Particularly, each map-patch of slope type is the patch of the landscape, all map-patches belonging to the same slope type constitute the class of the landscape, and all the classes constitute an integrated landscape. Then the slope map patch could be used to depict the patch's spatial structural features, such as relative size, shape, aggregated degree, connectivity degree, etc. Therefore, based on the loess terrain and landscape features, the theory and methodology of landscape ecology could be applied to study the spatial structure of slope distribution.

II. MATERIAL

A simulated loess watershed, where the loess material and relief properly represent the true loess surface, is adapted to investigate the variation in slope landscape with loess watershed evolution. The evolution of the simulated loess watershed was driven by the exogenetic force of artificial rainfall. For a period of three months, twenty artificial rainfall events with different intensities and durations were carried out. In the process, nine DEM data sets, each with 10 mm grid resolution, were established by the method of close-range photogrammetry [10]. The slope types were then classified base on these DEMs with the way of object oriented classification (Fig.1) [10, 11]. Then five landscape indices, including Mean patch area (*AREA_MN*), Perimeter-Area Fractal Dimension (*PAFRAC*), Interspersion and Juxtaposition Index (*IJI*), Patch Cohesion Index (*COHESION*), are applied to quantify the slope landscape.

TABLE I. GEOMETRIC FEATURE OF SIX SLOPE TYPES (ND MEANS NO DEFINITION)

Slope form		Geometric feature		
		plane curvature	profile curvature	Slope gradient
LL slope		±0	±0	ND
VV slope		>0	>0	ND
CC slope		<0	<0	ND
VL slope		±0	>0	ND
CL slope		±0	<0	ND
flat slope		ND	ND	≤3

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III. RESULT AND DISCUSS

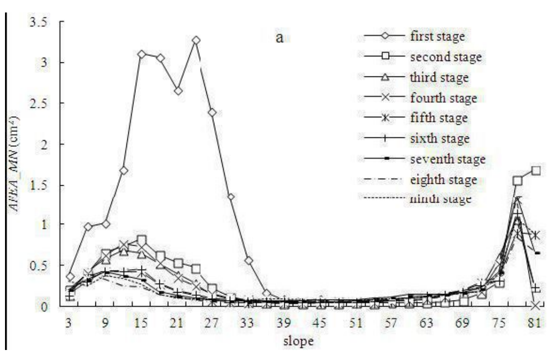
Fig. 1 shows the distribution of the slope map-patch indices at different stages at class level, which can depict the spatial structure of the patches for different slope classes.

1) Relative size and shape of patches:

AREA_MN of the slope patch was found to have a sudden decrease with continuing rainfall. The peak value of the curve falls in the interval between 0.8 and 3.5 cm2, which reveals a high sensitivity of original loess surface to irreversible accelerated erosion. Overall, Fig. 1-a shows that the relative size of the patches is rather small, while the heterogeneity degree is high. *PAFRAC* at different stages varies from 1.17 to 1.83. Following the increase of the slope, *PAFRAC* of the simulated watershed shows the same trend, as does the complexity of the patches. The aforementioned variation of the slope patches indicates that once the rainfall erosion began, the original smooth loess surface became more complicated, i.e., the increasing surface roughness and gully enlargement accelerated headward erosion.

2) Spatial structure of patches:

An *IJI* value approaching 0 indicates that the target patch type is spatially adjacent to only one other patch type, and that the number of patch types increases. An *IJI* value equal to 100 represents spatially adjacent patch types that are equal in length, i.e., the possibility of adjacent patches is equal. *IJI* at slope gradients of 27- 60° are bigger than at other slope classes, showing that slope patches in hillslope areas are more dispersed than in flat areas, e.g., valley areas and interfluve areas. This reveals the phenomenon that gully headward erosion enlarges the degree of fragmentation in the simulated watershed. *COHESION* of all stages almost changes from 70-100%. To most stages, the minimum values appears at slope 39-54°which shows that in high relief areas, the degree of slope patch fragmentation and dispersion are high. This indicates that the continuity of the origin loess surface will change quickly following the watershed evolution driven by rainfall erosion.



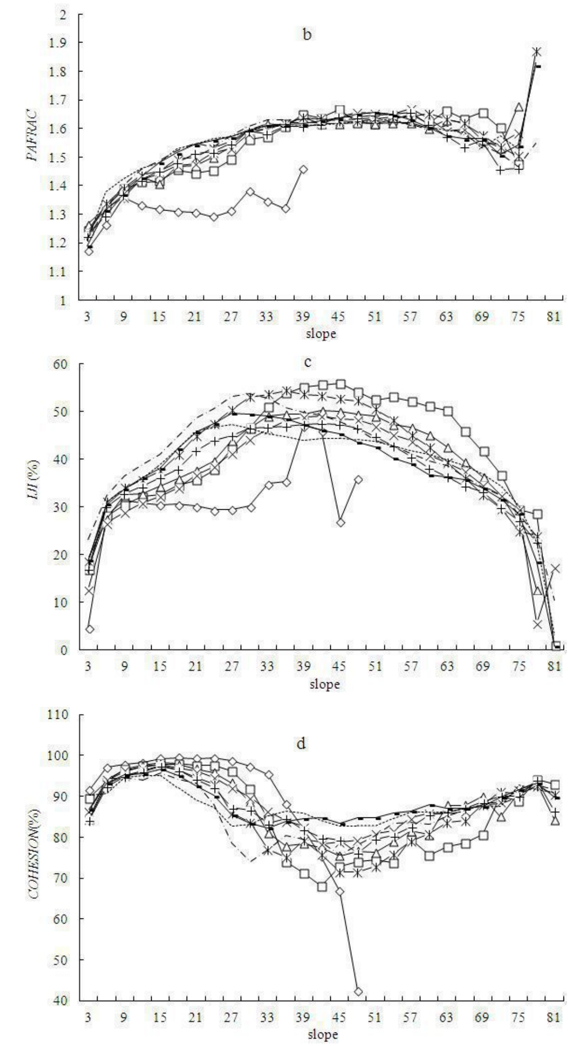
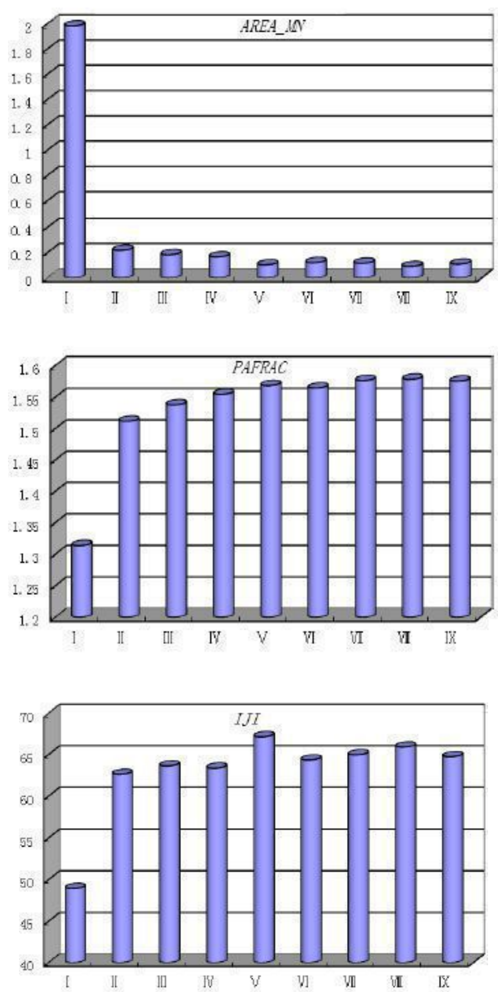


Figure 1. Comparison of slope landscape indices in different stages

Fig.2 shows slope patch structure of different stages at landscape level. Four indices show different variation patterns that could be classified into two groups. One group includes *PAFRAC* and *IJI*，which shows rising tendency on a global level following the evolution of the simulated watershed. Another group, including *AREA_MN*, and *COHESION*, shows opposite trend with the first group. The *PAFRAC* and *IJI* in the early period are smaller than in the later period, while the *AREA_MN* and *COHESION* in the early period are greater than in the later period. This suggests that, in the early period of simulated watershed, fragmentation of the patches of slope class is rather small, the slope patches distribution is consecutive, and the patch shape is more regular than in the later period. The loess surface in the early period is smooth, so the *AREA_MN* is larger than in the later stage. This also suggests that, in the early period, fragmentation of slope patches is large, the patches distribute connectively, and the patch shape is more regular than in the later stage. Actually, *PAFRAC* at different stages show little difference (ranging from 1.314–1.576), which indicates comparability of the patch shapes in general. This is the same as the indices at class level. All the indices vary following the evolution of the simulated watershed.



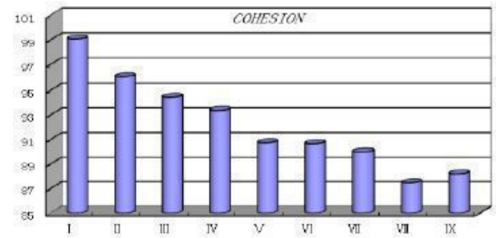


Figure 2. Slope landscape indices at landscape lever

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