# Research on Terrain Landscape System based on Complex network

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*Abstract*—**This paper described study hilly area of the Loess Plateau watershed system using complex network theory, and terrain landscape network was established. Some indexes such as degree, average path length and clustering coefficient were selected as measure. Some results included that terrain landscape network is the typical small world characteristic network, has disassotativity characteristic, and is not a kind of scale-free network. The topology feature of terrain landscape is not affected by the geographic scale. Under the artificial modification, the terrain landscape network had been changed the topology structure of network. Its average degree was reduced and its clustering coefficient was increased. The watershed hydrological characteristics about system had been influenced because of the change of system structure. It was shown that complex network is a new method for studying the landscape evolution on the drainage basin.**

## I. INTRODUCTION

On the Loess Plateau, There are many styles of landform, and the skeleton of terrain is constructed by terrain feature points and lines. The terrain features such as peaks; runoff nodes occupy the transfer of terrain energy, and reflect the different hydrological characteristics on the local terrain landscape system. The structure of terrain landscape on the Loess Plateau is marvelous and complex. In the system opinion, many complex systems in nature can be described by network, e.g. river network, transport network and social network [1-3]. Geomorphic systems consist of coupled subsystems with trait of small world networks, characterized by tightly connected clusters of components. This spatial complex network showed that these networks have nodes and links which are constrained by some geometry and are usually embedded in three dimensional spaces and this has important effects on their topological properties and consequently on process which take place on them.

Terrain landscape system as a kind of geomorphic system can be characterized as a set of interconnected components, which may be objects, process or regimes, or nature phenomena or events. These components are connected by fluxes of matter and energy, feedbacks, spatial or temporal sequencing or connectivity and process-response relationships. This paper discussed a novel method based on complex network theory, to analyze terrain landscape system function change after artificial affect. For purposes of illustration, the method is applied to landform landscape system on the Loess plateau.

## II. DATA AND METHODS

### *A. Data*

The study area is located on Suide County in China. The experimental data was obtained from digitized contour of topographic map at a scale of 1:10000 and 5m resolution. The projection of DEM is Gauss-Kruger. DEM data is provided by Shaanxi Bureau of Surveying and Mapping.

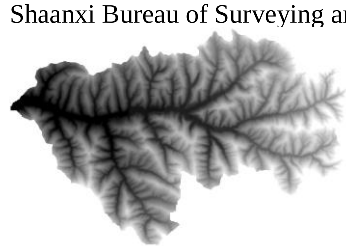

Fig1. DEM of test area

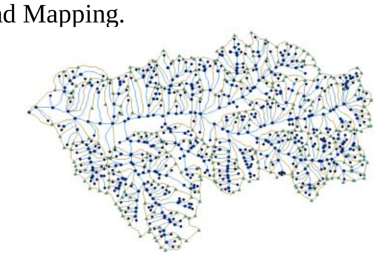

Fig2. All nodes of network

In terrain landscape, many feature points control the distribution of watershed energy, which include the peak and node of ridge on the positive terrain, gully head and runoff node on the negative terrain. So complex network for terrain landscape can be abstracted as follows:

TNet = network (peak, gully head, runoff node)

All feature points of terrain landscape system need to be connected. Edges of network included as follows rules:

(1) The edge is between peaks with points of ridge intersection in the positive landform.

(2) The edge is between peaks and points of ridge intersection in the positive landform with runoff node and gully head in the negative landform.

(3) The edge is between gully head with runoff node in the negative landform.

All nodes and edges of network were extracted by DEM data, which was adopted by method of digital terrain analysis.

### *B. METHODS*

Method of complex network is abstractly reflected natural system using network elements (nodes, edges), and expressed the link of various objects in reality. These types of networks were termed "small-world" networks [4]. There short cuts across the graph to different clusters of vertices introduced a level of efficiency not predicted in the ER model, and showed the first signs of self-organization in complex networks. In 1999, Barabási found scale-free network that its degree distribution is not a Poisson or exponential distribution [5], but a power law distribution. Meanwhile, complex networks of grow over time, and new vertices attach preferentially to already well-connected vertices in the network.

When examining dynamical terrain landscape systems connected by a network of interactions, two aspects of the problem can be considered independently. These are the dynamics of the individual uncoupled subsystems, and the topology of the interaction network. A network about terrain landscape on the Loess plateau consists of N nodes or vertices and m edges (the connections or relationships among components). The abstract networks may be directed, signifying the direction of causality or influence, or undirected, simply signifying that many components are related. A net is considered connected if it is possible to follow a path of one or more edges between any two vertices.

Some important characteristics of complex network include average degree, degree distribution, average path length, clustering coefficient and assortative coefficient.

## III. RESULTS

### *A. Statistic terrain landscape network*

The complex network of terrain landscape had been established depended on DEM, and its network expressed the structure of natural drainage system. The characteristic of complex landscape network is that node is 921, edge is 1778, average degree is 3.77, clustering coefficient is 0.22, and average path length is 14.82. The clustering coefficient and average path length of this random network is 0.004 and 5.14 respectively. Form it, one clearly appreciates that the values of the clustering coefficient are much larger than those corresponding to the associated classical random graphs. The values of the average path length are also to be very small. Thus, terrain landscape networks are in fact small world network. At the same time, we could be found that the distribution of node is exponential type, and is not power law distribution (figure 3). The networks have not scale free feature. However, runoff node as only node in this network (figure 4), this node is obey power law distribution and it can be as a kind of scale free network.

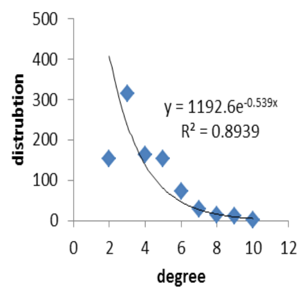


Figure3. Degree distribution of all nodes

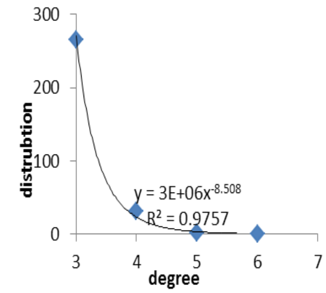


Figure4. Degree distribution of runoff nodes

In order to measure the link of all nodes about terrain landscape network, assortative coefficient is special index. In this network, its value was -0.19 and it was shown that the network is classified as dissortative network. Nodes whose degrees were high is priority to be connected with nodes whose degree was low. In complex terrain, degrees of some nodes were relatively high, and it controlled rather large geographical range. However, many nodes have low value of degrees, and all kinds of degree were spatial distribution of equilibrium.

### *B. Analysis of network evolution*

In order to soil and water conservation, some bars were constructed at the outlet of drainage, so that the original terrain landscape network had been changed in structure of natural system aspect. Fig.4 showed the distribution of bars. The completely continuous watershed system was dissected with 13 sub-watershed system. In this network, elevation about 13 nodes was heightened, so that control ranges of nodes were enhanced. Function of terrain network had been changed by human activity, and surface process was influenced in the watershed system.

From table1, clustering coefficient was lager and average path length on all 13 sub-networks was less than corresponding to the random graph. It was showed that 13 sub-networks were accord with small world network feature, and it was consistent with the whole terrain landscape network. So we can be concluded that the characteristic of network was not varied with geographical scales. In specific geographic space, network nodes were randomly distributed state with the drainage area was smaller. When watershed scale is become larger, small-world feature was increasingly presented. All of sub-networks in degree distribution aspect were not power law rules.

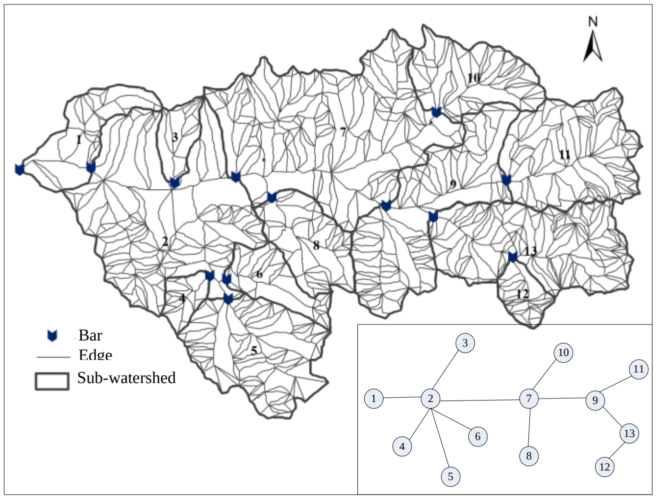


Figure5. Terrain landscape networks under artificial modification

Table1. the characteristic result of sub-network about watershed average degree, D, average path length, L,(corroding with random graph, $L_r$),the clustering coefficient, C, (compared with those of the random graphs, $C_r$)

| ID | Area（$km^2$） | D | L | $L_r$ | C | $C_r$ |
|---|---|---|---|---|---|---|
| 1 | 0.55 | 3.69 | 3.3 | 2.65 | 0.38 | 0.12 |
| 2 | 2.13 | 3.59 | 6.1 | 3.88 | 0.2 | 0.03 |
| 3 | 0.23 | 3.24 | 2.65 | 2.59 | 0.19 | 0.15 |
| 4 | 0.17 | 3.42 | 2.78 | 2.58 | 0.25 | 0.14 |
| 5 | 1.08 | 3.78 | 5.5 | 3.41 | 0.26 | 0.04 |
| 6 | 0.37 | 3.43 | 3.8 | 2.88 | 0.27 | 0.10 |
| 7 | 2.50 | 3.47 | 7.37 | 4.21 | 0.17 | 0.02 |
| 8 | 0.59 | 3.40 | 4.68 | 3.35 | 0.31 | 0.06 |
| 9 | 1.35 | 3.50 | 6.92 | 3.88 | 0.19 | 0.03 |
| 10 | 0.71 | 3.70 | 4.67 | 3.13 | 0.29 | 0.06 |
| 11 | 1.14 | 3.65 | 5.81 | 3.58 | 0.28 | 0.04 |
| 12 | 0.21 | 4.08 | 2.63 | 2.26 | 0.4 | 0.17 |
| 13 | 1.52 | 3.76 | 6.51 | 3.73 | 0.23 | 0.03 |

When human behavior was active on the watershed system, some topology characteristic of network would be changed. The average degree of network after artificial modification was 3.6, which is less than original network, and nodes relationship in network was weaken. The outlet importance of 13 sub watershed was stronger than the other nodes, breaking the distribution of the original network energy. Average path length became decrease with network scale lessening, and the connectivity of sub network was reducing, so that coupling feature about terrain landscape system was weak. Under the artificial effect, the modular of terrain landscape network was significant. When the structure of basin system had changed, the runoff slope length was reduced, and system hydrological function had been influenced.

According to the soil and water conservation data from Suide station, it was indicated that the hydrology and sediment transport function of this basin has been changed obviously. The measures for soil and water conservation is rather good, runoff modulus decreased by 24% and sediment transport module reduced 50%.

## IV. CONCLUSION

We have discussed the spatial complex network approach to shed new light on complexity of the phenomenon about terrain landscape system. The topological properties of terrain network constructed from DEM on Suide County have been analyzed. We have shown that the terrain landscape is “small-world” networks. The local network about runoff node is scale-free network characterized by the power law connectivity distribution. Geographical scale changes have little effect on the structure characteristic of complex terrain landscape network. After artificial modification, complex network of terrain landscape have evolved as for some bars embed in the spatial network. These key nodes controlled surface network process, changed local base level of erosion, and influenced the hydrological feature in this watershed system. It was our expectation that spatial complex network approach may lead to deeper understanding of terrain landscape system.

## ACKNOWLEDGMENT

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