ECOPERSIA

DOI: 10.18869/modares.Ecopersia.5.3.1887 **2017, 5 (3):1887-1901**

Comparison among Allometric Relations of Some Morphometric Characteristics under Natural and Simulated Scales

Leila Goli Mokhtari[1]*, Mohammad Hossein Ramesht[2], Mehdi Momeni Shahraki[3]

[1] *Assistant Professor, Department of Geomorphology and Climatology, Faculty of Geography and Environmental Science, Hakim Sabzevari University, Sabzevar, Iran*
[2] *Professor, Department of Physical Geography, Faculty of Geographical Science and Planning, University of Isfahan, Isfahan, Iran*
[3] *Assistant Professor, Department of Surveying, Faculty of Engineering, University of Isfahan, Isfahan, Iran*

** Corresponding author: Department of Geomorpholohy and Climatology, Faculty of Geography and Environmental Science, Hakim Sabzevari University, Sabzevar, Iran, Fax: +98 514 401 3270, Tel: +98 915 325 6746, Email:l.mokhtari@hsu.ac.ir*

Received: 4 April 2017 / Accepted: 19 June 2017 / Published Online: 23 September 2017

Background: The concept of allometry states that the relative rate of change of a system unit is a constant fraction of the relative rate of change of the entire system, or of another part of the system. This concept is stated as a nonlinear relationship and has been verified in a variety of natural systems.
Materials and Methods: The allometric relations in various phases of basin evolution in forms of static and dynamic models was investigated. In order to study the dynamic allometry, a model consisting of two basins was developed. The evolution stages and the erosion changes caused by artificial rainfall and tectonic movements and also in static form (natural basins) were monitored.
Results: The existence of allometric relations in drainage basins that are progressing toward the equilibrium (natural basins and basins affected by erosion) are significant and verifiable. This kind of relations do not exist in tectonic affected basins that were moving away from the equilibrium.
Conclusions: Allometric relations in drainage basins can define different states of system such as equilibrium. Moreover, any factor that causes the basin to move away from equilibrium needs to have an initial effect on basin relations to cause disorder in the system, and this change, in many cases, can be formulated or demonstrated by allometric model. Therefore the allometric equations could be considered an important tool in predicting the evolution of drainage basins and assessing their performance in the past and present.

Keywords: Allometry, Drainage basin, Morphometric Characteristics Experimental basin, Tectonic movements

1. Background

The study of relationsof drainage basins as natural systems has always been of environmental interests. Since drainage basin is the main unit in drainage systems, many studies have been conducted in this area. Interms of linear and nonlinear systems of classification, drainage basins are often regarded as nonlinear systems. A system is considered nonlinear if the outputs are disproportionate to the entire range of the inputs (1). Features of nonlinear geomorphic systems are that they can demonstrate complex behaviors such as dynamical equilibrium and deterministic chaos (2).

[Downloaded from ecopersia.modares.ac.ir on 2025-05-18]

[DOR: 20.1001.1.23222700.2017.5.3.2.4]

The concept of allometry states the relative rate of change of a system unit is a constant fraction of the relative rate of change of the entire system, or of another part of the system (3). Gould states that allometry is a general term that defines any dynamic or static relationship fit by power functions and involves changes in shape correlated with size increase (4 , 5). These power laws are emergent general features of complex systems (6); however, species-area curves and body-size allometry have not been derived from theory and these scaling relations were empirical, estimated by regression rather than being calculated from a set of theoretical statements (7).

Huxley was the first to demonstrate the simple and significant relation between the magnitudes of the two variables of a system (8).In typical cases, if x is the magnitude of the animal (as measured by some standard linear measurement, or by its weight minus the weight of the organ) and y is the magnitude of the differentially-growing organ, then the relation between them is $y = bx^k$, where b and k are constants. This can also be written as $\log y = \log b + k \log x$, which means that any magnitude following this formula will fall along straight lines if plotted on a double logarithmic plot(8).These types of allometric relationships can be referred to as power or scaling laws (9), which permit extrapolation and prediction over a wide range of scales, and some materialize as universal and offer basic clues (6). The same scaling laws in biology are responsible for a phenomenon called differential growth, the problem of which is a chief problem in natural science. Similarities between evolving basins and growing organisms have led us to evaluate basins based on the allometric framework.

Woldenberg (10) was one of the first researchers who applied the allometric concept to analyze relations between discharge, area and stream order) in rivers as open systems. Bull (11) used a power function to describe the relation between fan areas and its respective source areas. A number of studies have shown allometric relations in geomorphology such as delta (12), specific sediment yield (13) and cirques (14,15). Also, Brook *et al.* (16) provided a model of cirque evolution where rates of change over space was properly substituted for rates of change over time and suggested that cirques lengthened at a faster rate than they deepened, and broadened at only a piecemeal rate in comparison to lengthening. Mindrescu and Evans (17) through a complete inventory of the 631 glacial cirques in Romania (and adjacent Ukraine) concluded that these cirques were scale specific and developed allometrically, extending in length more rapidly than they deepened and shape changed with size. Hadian-Amiri *et al.* (18) investigated a practical relationship to connect landslide area to landslide volume from a dataset of 142 landslides and fitted to the observed data and found that the power law fit the data better than other models. Hood (19) developed allometric models predicting the number and size of tidal channels that could develop following salt marsh restoration; tidal channel allometry showed similar scaling exponents for channel plan form metrics between locations. Channel size and complexity were positively related to tidal range and negatively related to wave height. Pourkhosravani and Goli Mokhtari (20) investigated the growth relations in 103 nebka's morphometric properties in order to define the principles of management in nebka growing areas. Results showed that studied nebkas had allometric growth and height dimension grew faster than the other dimensions. However, study of landform allometry is currently limited to 2 or 3 landforms and needs to be improved and comprehensive in future works.

Studies of allometry fall into two distinct areas: (i) dynamic, in which organisms at various stages of growth are compared, and (ii) static, the study of scale-related changes in a population without regard for the course of development of an individual member (21).

[Downloaded from ecopersia.modares.ac.ir on 2025-05-18]

[DOR: 20.1001.1.23222700.2017.5.3.2.4]

2. Objective

The current practice is to analyse allometric relations in drainage basins in the forms of static (natural basins) and dynamic (experimental basins), and to determine allometric relations through the application of regression procedures.

3. Materials and Methods

3.1. Data

The data used in this study were obtained from two sources: (i) natural basins, the data of which were extracted from Digital Elevation Models (DEM), and (ii) experimental landscapes, the data of which were obtained through constructing a drainage basin evolution model under erosional activities as well as tectonic movements.

3.2. Natural basins

Due to lack of sufficient long term data on the landscape evolution, geomorphologists observe landforms at various stages of development and, therefore, make inferences about changes through time, based on various forms currently available (22). In this way, often termed ’ergodic, spatially-sampled data are substituted for time series, a concept borrowed from statistical mechanics (22).

To derive basin characteristics from digital elevation models (DEMs), 17 natural basins were selected (Figure 1). Since channel networks contain crucial information about a basin (23), investigations of drainage network properties and relations were the central issue in studying size related changes in 17 basins. For this purpose, the following variables were measured: basin area, total channel length, main stream length, stream order based on the Strahler stream ordering system (24), number of first order channels, and number of nodes (links in the drainage network).

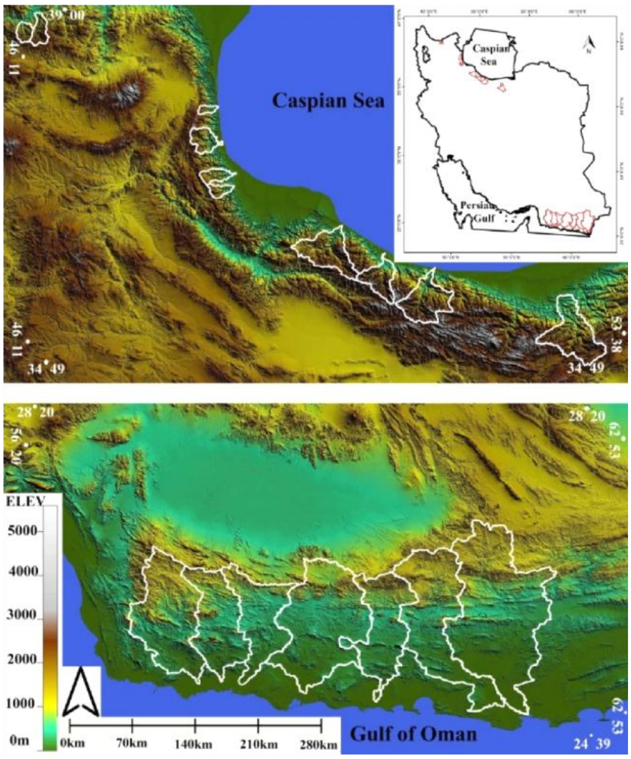


Figure 1 locations of 17 studied basins in Iran

[Downloaded from ecopersia.modares.ac.ir on 2025-05-18]

[DOR: 20.1001.1.23222700.2017.5.3.2.4]

[Downloaded from ecopersia.modares.ac.ir on 2025-05-18]

[DOR: 20.1001.1.23222700.2017.5.3.2.4]

3.3. Modeling drainage basins

There are many models with a number of advantages and limitations for watershed processes simulation (25), but scaled experimental basins help us to understand the basin evolution under controlled conditions. The use of scaled physical models, usually in a laboratory setting, is an important means to overcome the time and energy costs of investigating in the field. Moreover, these models form an essential bridge between the scales that we can observe and the generally larger scales that we seek explanations and forecasts (26).

3.3.1. Experimental basin design and material characteristics

Our experiment was designed to explore basin development under two different conditions: (i) erosional, and (ii) erosional plus uplift activities. The landscape simulator consisted of a sprinkler system above the area containing erodible soil (20 micron average grain size distribution) with the initial topography in the form of a hill (length=4.8 m, width=2 m, height=2.15 m), and also a tectonic simulator device to create tectonic movements that consisted of a 40 cm diameter plate and a control unit to direct the uplift and time. The sprinkler system produced raindrop of about 0.5 mm in size (Figures 2, 3). As basins and their drainage networks evolved in different ways, depending on their initial topography (27), in order to simulate a basin in the early phases of an erosional cycle, a high relief was prepared as the initial topography. Moreover, the experiment was designed in open air and there was no limitation for runoff and sediment transfer.

Precise ground control points in different locations were obtained to extract high-quality DEMs and a scale bar helped us to calculate the scale. Following each rainfall event, the surface was allowed to drain, and to detect morphological change through the landscape evolution, two types of imagery from three different angles (at least 120 photos for each level) were taken to prepare stereo-pair and grid photographs.

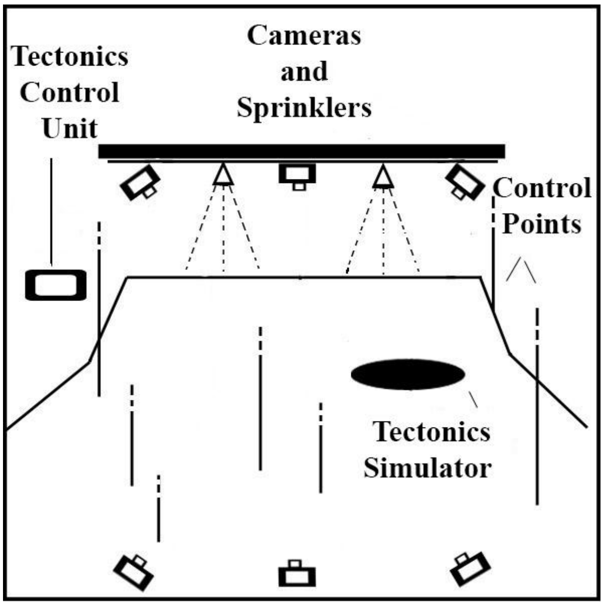


Figure 2 The landscape simulator

Figure 3 The initial steps of tectonics simulator setting

Tectonic uplift is one of the main parameters that control erosion and relief dynamics at the earth's surface at geological timescales, so the incorporation of an uplift device is essential for modeling purposes (28). During tectonic activities, in order to compare changes in relationships in uplift and non-uplift situations, the model was divided into two basins. One basin experienced uplift besides erosional activities and in the other basin only erosional activities were performed and after each level of rainfall, changes in topography were recorded. During seven months of erosional activities on the model surface, 130 cm of the hill's elevation in basin "a" (only erosional activities) and 136 cm in basin "b" (erosional + tectonic activities) were removed and totally 27 cm of uplift occurred in basin "b".

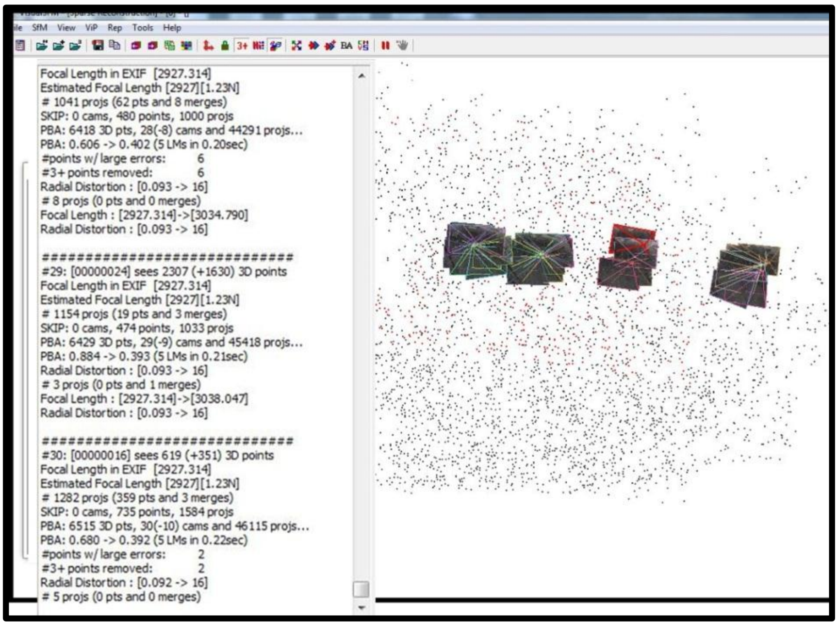
3.3.2. DEM generation

Photogrammetry was used because of three main benefits inherent in it: (i) it is a 3D coordinate extraction method with a relatively low cost coverage of all points on the simulated hill and flexible distance/accuracy, (2) computational control of measurement accuracy, and (3) documentation of all the measurements and states of the simulated hill. In this study, we designed the configuration of photogrammetry to limit the 3D coordinate error to 5 mm. The images were taken using a geometrically calibrated Canon 50D DSLR camera and in order to obtain more precise details, the images were taken in RAW format.

Visual SFM was used for 3D reconstruction. The selected images were imported to Visual SFM to extract point clouds for each level. In Visual SFM, after feature matching between the images, sparse reconstruction was performed and then dense reconstruction was obtained using the Yasutaka Furukawa's CMVS/PMVS tool. Figure 4 shows a sparse reconstruction phase in Visual SFM and Figure 5 shows the dense point clouds extracted for the 17 steps of the basin evolution. Finally, the point clouds for the different levels were matched against each other and their coordinates were unified. Afterwards, after removing the noises and unwanted parts, triangulation and DEM extraction were performed using GIS. Using Arc Hydro tools, the flow direction layer was prepared based on the eight direction pour point model (D8) (29). This model approximates the surface flow using eight discrete grid directions and then the drainage basin and drainage networks were delineated for analysis. The erosional activities were recorded in the 17 steps for each basin and in order to investigate the basin properties the following variables were emphasized: basin area, total channel length, main stream length, stream order, number of first order channels and number of nodes (links in drainage network).

[Downloaded from ecopersia.modares.ac.ir on 2025-05-18]

[DOR: 20.1001.1.23222700.2017.5.3.2.4]



```
Focal Length in EXIF  [2927.314]
Estimated Focal Length [2927][1.23N]
# 1041 projs (62 pts and 8 merges)
SKIP: 0 cams, 480 points, 1000 projs
PBA: 6418 3D pts, 28(-8) cams and 44291 projs...
PBA: 0.606 -> 0.402 (5 LMs in 0.20sec)
#points w/ large errors:        6
#3+ points removed:             6
Radial Distortion : [0.093 -> 16]
# 8 projs (0 pts and 0 merges)
Focal Length : [2927.314]->[3034.790]
Radial Distortion : [0.093 -> 16]

##############################
#29: [00000024] sees 2307 (+1630) 3D points
Focal Length in EXIF  [2927.314]
Estimated Focal Length [2927][1.23N]
# 1154 projs (19 pts and 3 merges)
SKIP: 0 cams, 474 points, 1033 projs
PBA: 6429 3D pts, 29(-9) cams and 45418 projs...
PBA: 0.884 -> 0.393 (5 LMs in 0.21sec)
Radial Distortion : [0.093 -> 16]
# 3 projs (0 pts and 1 merges)
Focal Length : [2927.314]->[3038.047]
Radial Distortion : [0.093 -> 16]

##############################
#30: [00000016] sees 619 (+351) 3D points
Focal Length in EXIF  [2927.314]
Estimated Focal Length [2927][1.23N]
# 1282 projs (359 pts and 3 merges)
SKIP: 0 cams, 735 points, 1584 projs
PBA: 6515 3D pts, 30(-10) cams and 46115 projs...
PBA: 0.680 -> 0.392 (5 LMs in 0.22sec)
#points w/ large errors:        2
#3+ points removed:             2
Radial Distortion : [0.092 -> 16]
# 5 projs (0 pts and 0 merges)
```

Figure 4 Sparse reconstruction in VisualSFM phases

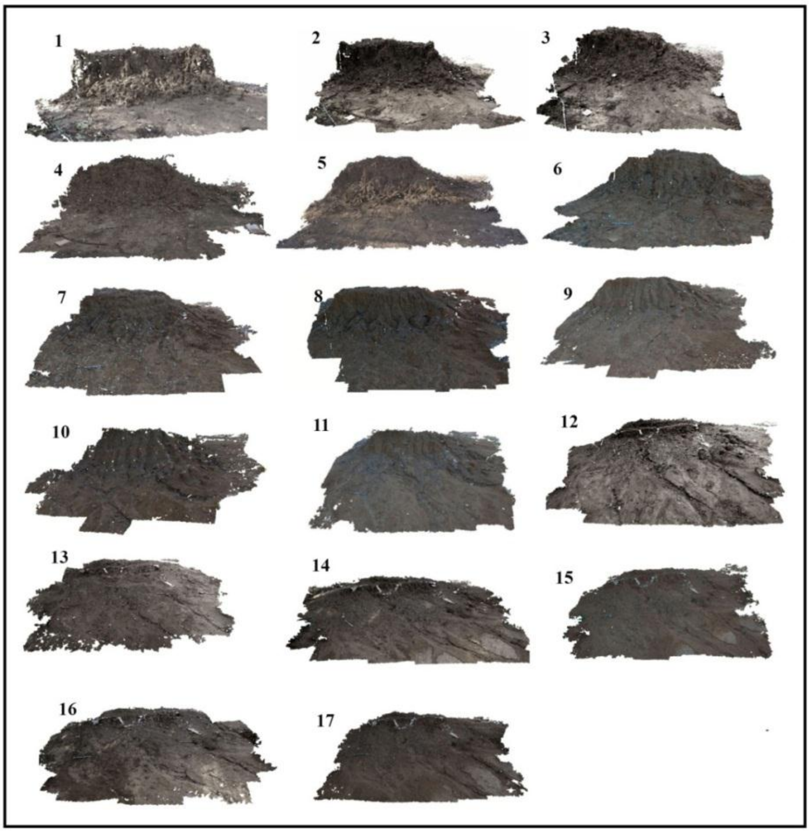


Figure 5 Dense point clouds for 17 steps of landscape evolution

[Downloaded from ecopersia.modares.ac.ir on 2025-05-18]

[DOR: 20.1001.1.23222700.2017.5.3.2.4]

3.3.3. Data accuracy

Geometrical quality control during the point clouds' matching showed that the relative accuracy of the point reached 21 mm as the maximum error. The statistical maximum error is interpreted as 8.5 millimeters STD when maximum error equal to 2.5*STD is conservatively considered. The STD can be computationally reduced due to the large amount of computation; hence, an average of 450000 points in the area is equal to about 4 points in every square centimeter. If every 4 close points are averaged, the relative error reduces to 1.2, so the 8.5 mm STD will reach 4.25 mm. The averaging process was done during the noise removal and mesh generation by GIS.

4. Results

4.1. Natural basins and their allometric relations

Regression analysis among variables (Table 1 and Figure 6) showed that the total channel length and number of nodes in 17 natural watersheds were the most closely related variables to the area. These relations were followed by number of the first order channels and main stream length. The strongest relation to the main stream comes from total channel length and number of nodes (R^2= 0.944, 0.924). Stream order had a comparatively weaker correlation with main stream length (R^2= 0.777).

Table 1 Relationships between variables for 17 study natural drainage basins

Variable 1	Variable 2	Exponent	R^2	P-value	95% conf.	Mean	Std Error of Estimate
Basin area	Total channel length	1.074	0.999	0.000	1660.87 – 5469.08	3417.43	0.049
	Number of nodes	0.999	0.995	0.000	641.26 – 2066.47	1319.76	0.112
	Number of first order channels	0.992	0.994	0.000	690.07 – 2078.20	1344.23	0.122
	Main stream length	0.597	0.943	0.000	92.58 – 196.11	141.23	0.224
	Stream order	0.139	0.855	0.000	5.18 – 6.23	5.70	0.087
Main stream length	Total channel length	1.697	0.944	0.000	1721.48 – 5471.71	3417.43	0.388
	Number of nodes	1.566	0.924	0.000	678.86 – 2031.98	1319.76	0.420
	Number of first order channels	1.552	0.921	0.000	664.82 – 2098.22	1344.23	0.426
	Stream order	0.216	0.777	0.000	5.12 – 6.30	5.70	0.108
Total channel length	Number of nodes	0.929	0.993	0.000	668.27 – 1998.84	1319.76	0.129
	Number of first order channels	0.922	0.992	0.000	710.44 – 2076.24	1344.23	0.136
	Stream order	0.130	0.854	0.000	5.18 – 6.23	5.70	0.088
Stream order	Number of first order channels	6.188	0.878	0.000	690.10 – 2079.32	1344.23	0.080
	Number of nodes	6.21	0.874	0.000	685.25 – 2048.16	1319.76	0.081
Number of first order channels	Number of nodes	1.007	0.999	0.000	696.90 – 1986.43	1319.76	0.050

[Downloaded from ecopersia.modares.ac.ir on 2025-05-18]

[DOR: 20.1001.1.23222700.2017.5.3.2.4]

Regarding relationships for the total channel length, coefficients for determinations were 0.993 for the number of nodes and 0.992 for number of first channels and the weakest relation between the total channel length and other variables belonged to stream order (R^2= 0.854).

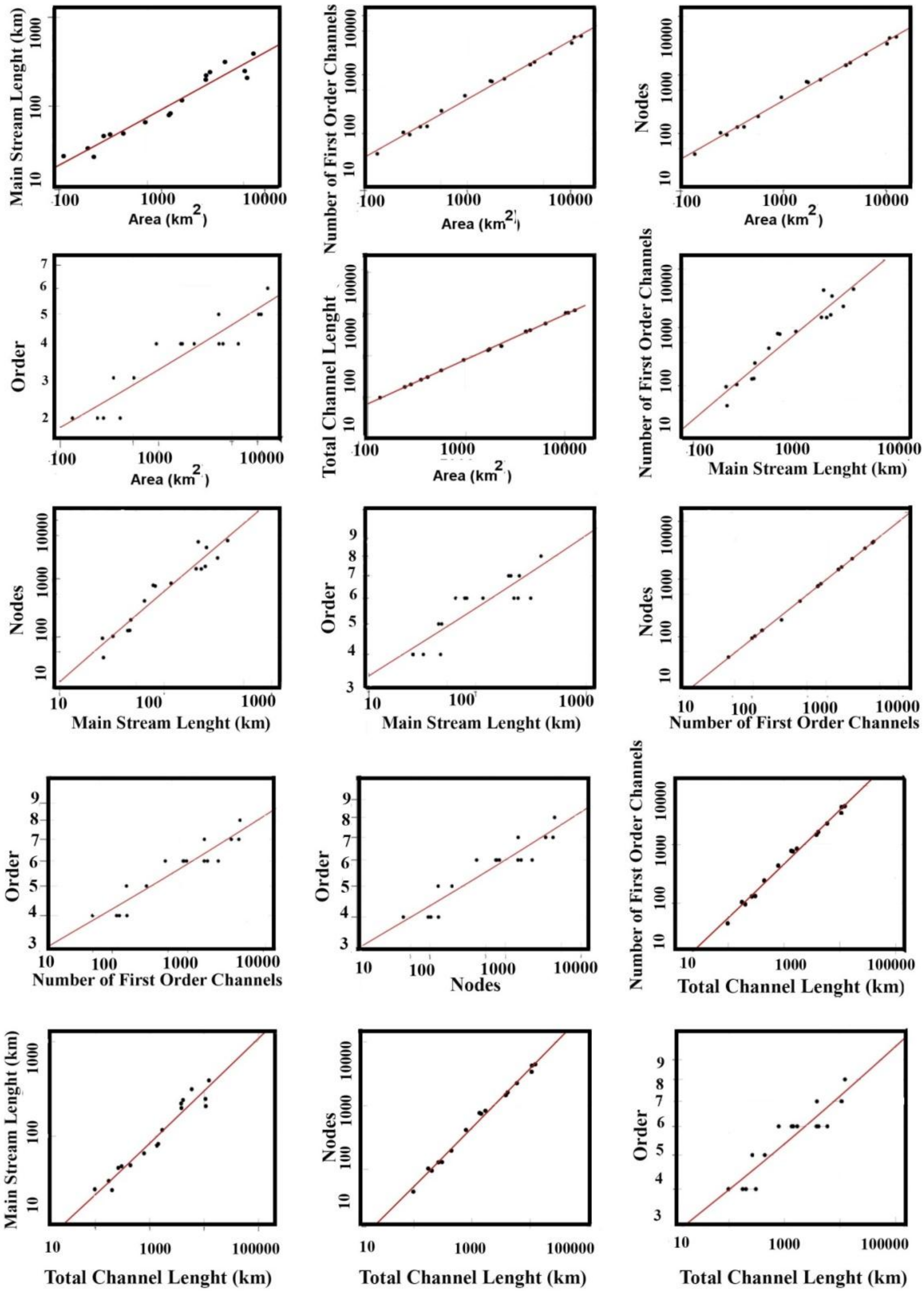


Figure 6 Regression results for natural basins

[Downloaded from ecopersia.modares.ac.ir on 2025-05-18]

[DOR: 20.1001.1.23222700.2017.5.3.2.4]

4.2. Experimental landscapes

The complexities of natural processes make it very difficult to model. Also, results from experimental model have several limitations in extrapolation from the experimental scale to natural drainage basins. A particular challenge in modeling arises when information is transferred across scales in space and time, because as the dimensions of time and space change, cause–effect relationships may be obscured or even reversed (30), therefore downscaling process and conditions in a model become a very difficult task. For example, natural rainfall conditions are very difficult to simulate because of raindrop size, its proportion to surface, and relative force of impact and intensity. In addition, another problem is related to topography, because relief is a product of long evolution and of coexistence of forms of various ages (31); moreover, different materials from erodible to non-erodible could not be simulated completely as well.

4.2.1. Basin "a" and its allometric relations

Main stream length, total channel length, and order and number of first channels all increased along with the basin area. In the case of the main stream in basin "a", R^2 ranged from 0.802 for total channel length to 0.232 for order. The number of first order channels and nodes increased the R^2 to 0.75.Although number of nodes and first channels were strongly correlated with total channel length (R^2= 0.913 and 0.920), order had the weakest correlation in this category (R^2= 0.405). Order had a weak relation with the first order channels (R^2= 0.497) and nodes (R^2= 0.470), but the number of first channels and nodes related with R^2increased to 0.991 (Table 2 and Figure 7).

Table 2 Relationships among variables for basin "a"

Variable 1	Variable 2	Exponent	R^2	P- value	95% conf.	Mean	Std Error of Estimate
Basin area	Main stream length	0.311	0.896	0.000	7.0 -7.4	6.8	0.058
	Total channel length	0.928	0.950	0.000	15.6- 24.2	19.7	0.117
	Stream order	0.203	0.336	0.015	3.0 -3.5	3.3	0.157
	Number of first order channels	1.149	0.841	0.000	18.7-32.1	25.1	0.275
	Number of nodes	1.287	0.856	0.000	16.6-30.7	23.3	0.290
Main stream length	Total channel length	0.309	0.802	0.000	15.6-24.2	19.7	0.234
	Stream order	0.513	0.232	0.050	3.0 -3.5	3.3	0.169
	Number of first order channels	3.292	0.745	0.000	18.7-32.1	25.1	0.348
	Number of nodes	3.683	0.757	0.000	16.6-30.7	23.3	0.378
Total channel length	Stream order	0.234	0.405	0.006	3.0 -3.5	3.3	0.149
	Number of first order channels	1.257	0.913	0.000	18.7-32.1	25.1	0.204
	Number of nodes	1.401	0.920	0.000	16.6 -30.7	23.3	0.217
Stream order	Number of first order channels	0.197	0.497	0.002	18.7 -32.1	25.1	0.490
	Number of nodes	0.173	0.470	0.002	16.6 -30.7	23.3	0.558
Number of first order channels	Number of nodes	1.105	0.991	0.000	16.6 -30.7	23.3	0.073

[Downloaded from ecopersia.modares.ac.ir on 2025-05-18]

[DOR: 20.1001.1.23222700.2017.5.3.2.4]

[Downloaded from ecopersia.modares.ac.ir on 2025-05-18]

[DOR: 20.1001.1.23222700.2017.5.3.2.4]

4.2.2. Basin "b" with tectonic movements and its allometric relations

In basin "b", the variation of number of nodes with first order channels (R^2= 0.936) were higher than the other variables, so the number of nodes could be well approximated by first order channels. Also, total channel length could be predicted during the growth of the basin area (R^2= 0.827), the correlation between main stream length and area was low (R^2= 0.408), and between the order and area correlation was weak (0.272.). R^2 for variation of total channel length with order suggested a weak correlation (R^2= 0.407) in basin "b", and all of the other correlations were insignificant (Table 3 and Figure7).

Table 3 Relationships among variables for basin "b"

Variable 1	Variable 2	Exponent	R^2	P- value	95% conf.	Mean	Std Error of Estimate
Basin area	Main stream length	0.304	0.408	0.006	6.3-7.1	6.7	0.091
	Total channel length	0.866	0.827	0.000	16.2-20.5	18.4	0.098
	Stream order	0.318	0.272	0.032	3.1-3.7	3.4	0.129
	Number of first order channels	0.123	0.012	0.680	20.1-27.1	23.6	0.280
	Number of nodes	0.129	0.014	0.654	18.2- 24.0	21.1	0.269
Main stream length	Total channel length	0.238	0.227	0.053	16.2- 20.5	18.4	0.207
	Stream order	0.023	0.000	0.945	3.1-3.7	3.4	0.151
	Number of first order channels	-0.755	0.100	0.217	20.1-27.1	23.6	0.267
	Number of nodes	-0.788	0.118	0.178	18.2- 24.0	21.1	0.255
Total channel length	Stream order	0.407	0.407	0.006	3.1-3.7	3.4	0.116
	Number of first order channels	0.497	0.173	0.097	20.1-27.1	23.6	0.256
	Number of nodes	0.468	0.166	0.104	18.2-24.0	21.1	0.248
Stream order	Number of first order channels	0.204	0.146	0.130	20.1-27.1	23.6	0.261
	Number of nodes	0.254	0.210	0.065	18.2-24.0	21.1	0.241
Number of first order channels	Number of nodes	0.930	0.936	0.000	18.2- 24.0	21.1	0.069

[Downloaded from ecopersia.modares.ac.ir on 2025-05-18]

[DOR: 20.1001.1.23222700.2017.5.3.2.4]

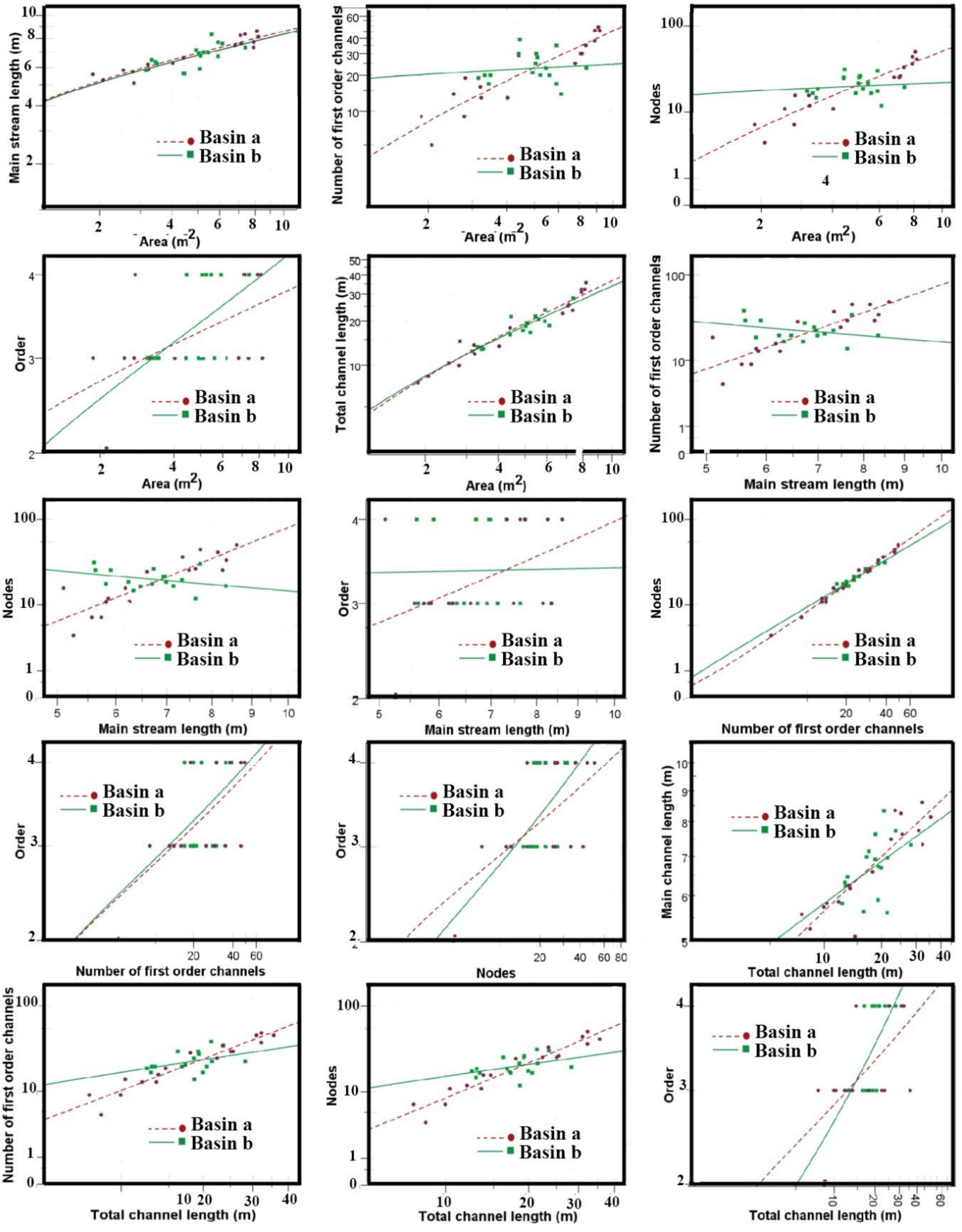


Figure 7 Regression results for experimental basins

5. Discussions

In natural basins, all of relationships are highly significant with a 95% confidence interval. The high R^2 confirms the significance of these relationships. The number of nodes has an exponent that is very close to unity (almost linear), implying that nodes increase in number as quickly as the number of first order channels grow. The correlation among variables in natural basins was very high in most cases (R^2= 0.777-0.999).

Analysis of allometric scaling in basin “a” showed that the relationships in this basin were weaker than the natural ones. The strongest relation referred to the total channel length (R2= 0.950) and the weakest belonged to the stream order (R2= 0.336).In basin "b", except some cases (correlations between number of nodes and first order channels, also between total channel length and basin area) other relations are weak or insignificant.

In recent decades a number of researchers (32,33) have concentrated their efforts on introducing drainage basins as open systems that tend toward a steady state. The concept of equilibrium is basic to the system theory (34). In the last two decades, attention to system behavior has moved away from determining single, stable equilibrium conditions to a mixture of equilibrium, disequilibrium, or nonequilibrium forms (35). Regarding allometric relations in the 17 natural basins, as systems that were near equilibrium, all of the relations were significant at $P<0.05$. In basin “a” as a system that tended towards equilibrium, most of the correlations were significant at $P<0.05$, but coefficients of determination were weaker than natural basins. Basin “b”, which was subjected to tectonic movements and was not near equilibrium condition, did not have any significant relations and no allometric relations could be traced. In this basin, the number of first order channels did not increase with the basin area. This kind of anomaly arises because of the intervening force of tectonic movements. Basins that are subjected to normal processes of erosion tend toward equilibrium and the relations among their elements are significant.

6. Conclusions

Analysis and subsequent evaluation of experimental and natural basins showed the following:

1- In more developed erosional cycles, allometric relationships are more significant. Basins that are subjected to tectonic movements do not have significant allometric relations among their elements. It seems that landscapes near the equilibrium has significant allometric relations. Therefore allometry can be used as an index for estimation of landscape distance from equilibrium.

2- This research has been done at a variety of scales from experimental landscapes to the natural scale. Each scale of analysis shows different aspects of the allometric relations and this kind of relation could be noted as an important factor in environmental systems.

3- Also, as another result, development of a drainage basin as a system needs the allometric relations to be established between elements as in natural basins and basin “a” in the current study. However, basin “b” after each level of precipitation completely changed and lost its identity and the patterns of channels were very dynamic and fluctuating and because of the lack of allometric relations, this basin could not act as a system.

Therefore, it appears that the allometric concept provides a valuable framework for studying the spatial variations in drainage network characteristics. Comprehensive use of these results, especially in the case of system concept, needs more work and the value of allometry in environmental science and geomorphology could be confirmed through practical applications in future.

[Downloaded from ecopersia.modares.ac.ir on 2025-05-18]

[DOR: 20.1001.1.23222700.2017.5.3.2.4]

Conflict of Interest

The Authors state that there is no conflict of interest.

Authors’ Contributions

All authors have participated sufficiently in the work including participation in the concept, design, analysis, or revision of the manuscript.

Funding/Support

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Acknowledgement

The authors gratefully acknowledge Dr. Ian Evans for his constructive comments on this manuscript.

References

1. Phillips JD. Sources of nonlinearity and complexity in geomorphic systems: Prog Phys Geog. 2003; 27: 1-23.
2. Phillips JD. Evolutionary geomorphology: thresholds and nonlinearity in landform response to environmental change: Hydrol Earth Syst Sc. 2006;10: 731-742.
3. Bull WB. Allometric change of landforms: Geol Soc Am Bull. 1975; 86: 1489-1498.
4. Mosley MP, Parker RS. Allometric Growth: A Useful Concept in Geomorphology?.Geol Soc Am Bull. 1972; 83: 3669-3674.
5. Goli Mokhtari L, Ramesht M, Almodaresi A. Analyzing of Surface Relations in an Experimental Drainage Basin.J Basic Appl Sci Res. 2013; 3(4): 120-124.
6. Brown JH, Gupta VK, Li B-L, Milne BT, Restrepo C, West GB. Complexity and biodiversity:The fractal nature of nature: power laws, ecological complexity and biodiversity.Phil Trans R Soc Lond B. 2002; 357: 619-626.
7. Schneider DC. The Rise of the Concept of Scale in Ecology. Bioscience; 2001; 51: 545-553.
8. Huxley JS. Problems of Relative Growth New york. The Dial Press; 1932.
9. Stevens C.F. Darwin and Huxley revisited: the origin of allometry. J Biol. 2009; 8 (14): 14.1-14.7.
10. Woldenberg MJ. Horton's laws justified in terms of allometric growth and steady state in open systems.Geol Soc Am Bull. 1966; 77: 431-434.
11. Bull WB. The alluvial-fan environment.Prog Phys Geog. 1977; 1: 222-270.
12. Wolinsky MA, Edmonds DA, Martin J, Paola C. Delta allometry: Growth laws for river deltas.Geophys Res Lett. 2010; 37: L21403.
13. Schiefer E, Slaymaker O, Klinkenberg B, Physiographically Controlled Allometry of Specific Sediment Yield in the Canadian Cordillera: A Lake Sediment-based Approach: Geogr Ann A, Series A-physical Geography. 2001; 83: 55-65.
14. Evans I.S. Allometric Development of Glacial Cirques: An Application of Specific Geomorphometry in Purves, R., Gruber, S., Straumann, R., and Hengl, T., (eds.), Geomorphometry 2009 Zurich. 2009; 248-253.
15. Crest Y, Delmas M, Braucher R, Gunnell Y, Calvet M, et al. Cirques have growth spurts during deglacial and interglacial periods: Evidence from 10Be and 26Al nuclide inventories in the central and eastern Pyrenees.Geomorphology. 2017; 278:60-77.

[Downloaded from ecopersia.modares.ac.ir on 2025-05-18]

[DOR: 20.1001.1.23222700.2017.5.3.2.4]

16. Brook MS, Kirkbride MP, Brock BW. Cirque development in a steadily uplifting range: rates of erosion and long-term morphometric change in alpine cirques in the Ben Ohau Range, New Zealand.Earth Surf Proc Land. 2006; 31: 1167-1175.

17. Mîndrescu M, Evans IS. Cirque form and development in Romania: Allometry and the buzzsaw hypothesis. Geomorphology. 2014; 208:117-136.

18. Hadian-Amri M, Solaimani K, Kavian A, Afzal P, Glade T. Curve Estimation Modeling between Area and Volume of Landslides in Tajan River Basin, North of Iran. ECOPERSIA. 2014; 2 (3): 651-665.

19. Hood WG. Geographic variation in Puget Sound tidal channel planform geometry. Geomorphology. 2015; 230:98-108.

20. Pourkhosravani M, Goli Mokhtari L. Analysis of growth relations of Nebkas in Dashte Negar Bardsir. Geographical Researche Journal. 2016; 31(1): 224-231 (In Persian).

21. Church M, Mark DM. On size and scale in geomorphology. Prog Phys Geog. 1980; 342: 342-390.

22. Paine ADM. Ergodic reasoning in geomorphology: time for a review of the term?.Prog Phys Geog. 1985; 9:1-15.

23. Tay LT, Sagar BSD, Chuah HT. Allometric relationships between traveltime channel networks, convex hulls, and convexity measures.Water Resour Res. 2006; 42.

24. Strahler AN. Quantitative analysis of watershed geomorphology: Transactions. American Geophysical Union. 1957; 38: 913-920.

25. Sareshtehdari A, Ghafouri M, Jafari Ardakani A, Bayat R. Reliability of Land Capability Map in Watershed Hydrological Simulation using SWAT Model. ECOPERSIA. 2014; 2(3): 715-725.

26. Kirkby MJ, A Role for Theoretical Models in Geomorphology? , *in* Rhoads, B.L., and Thorn, C.E., eds., The Scientific Nature of Geomorphology. Proceedings of the 27th Binghamton Symposium in Geomorphology, John Wiley & Sons Ltd. 1996.

27. Pelletier JD, Drainage basin evolution in the Rainfall Erosion Facility: dependence on initial conditions. Geomorphology. 2003; 53: 183-196.

28. Bonnet S, Crave A. Macroscale dynamics of experimental landscapes, *in* Buiter S.J.H, Schreurs G, eds., Analogue and Numerical Modelling of Crustal-Scale Processes. GEOL SOC Special Publication. 2006; 253:327-339.

29. O'Callaghan JF, Mark DM. The extraction of drainage networks from digital elevation data.Computer Vision, Graphics, and Image Processing.1984; 28: 323-344.

30. Schumm SA, Lichty RW. Time, space and causality in geomorphology. Am J Sci. 1965; 263: 110-119.

31. Starkel L. Space and time scales in geomorphology, Fourth International Conference on Geomorphology: Italy, Suppl. Geogr. Fis Dinam Quat. 1997; 61-66.

32. Chorley RJ. Geomorphology and general systems theory. Theoretical papers in the hydrologic and geomorphic sciences. 1962; 500-B: B1-B10.

33. Leopold LB, Langbein WB. The concept of entropy in landscape evolution.US Geological Survey Professional Paper. 1962; 500A: A1-A20.

[Downloaded from ecopersia.modares.ac.ir on 2025-05-18]

[DOR: 20.1001.1.23222700.2017.5.3.2.4]

34. Howard AD. Geomorphological Systems_Equilibrium and Dynamics. Am J Sci. 1965; 263: 302-312.
35. Phillips JD. The end of equilibrium?. Geomorphology. 1992; 5: 195-201.

مقایسه روابط آلومتریک برخی خصوصیات ریخت سنجی در مقیاس طبیعی و شبیه‌سازی

لیلا گلی مختاری[۱*]، محمدحسین رامشت[۲]، مهدی مومنی شهرکی[۳]

۱- استادیار، گروه ژئومورفولوژی و آب و هواشناسی، دانشکده جغرافیا و علوم محیطی، دانشگاه حکیم سبزواری
۲- استاد، گروه جغرافیای طبیعی، دانشکده جغرافیا و برنامه‌ریزی محیطی، دانشگاه اصفهان
۳- استادیار، گروه مهندسی نقشه‌برداری، دانشکده فنی و مهندسی، دانشگاه اصفهان

تاریخ دریافت: ۱۵ فروردین ۱۳۹۶ / تاریخ پذیرش: ۲۹ خرداد ۱۳۹۶ / تاریخ چاپ: ۱ مهر ۱۳۹۶

مقدمه: مفهوم آلومتری بیان می‌کند که نرخ رشد نسبی یک بخش از ارگانیسم نسبت به تمام ارگانیسم یا نسبت به بخش دیگری از سیستم رابطه‌ای ثابت است. این مفهوم به صورت یک رابطه غیرخطی بیان می‌شود و در بسیاری از سیستم‌های طبیعی اثبات شده است.

مواد و روش‌ها: در این مطالعه روابط آلومتریک در مراحل مختلف تحول حوضه به صورت مدل‌های دینامیک و استاتیک مورد بررسی قرار گرفته است. به منظور مطالعه آلومتری دینامیک مدلی با دو حوضه آبریز تهیه گردید. مراحل تحول و تغییرات این حوضه‌ها که تحت تاثیر فرسایش توسط باران مصنوعی بودند و یکی از آنها تحت اثر تکتونیک نیز قرار داشت ثبت شد و مورد ارزیابی قرار گرفت.

نتایج: نتایج نشان می‌دهد که وجود روابط آلومتریک در حوضه‌های آبریزی که به سوی تعادل تمایل دارند (حوضه‌های طبیعی و حوضه‌های تحت فرسایش) معنی‌دار است ولی این روابط در حوضه‌هایی که تحت تاثیر تکتونیک قرار دارند و از تعادل دور می‌شوند وجود ندارد.

بحث و نتیجه‌گیری: روابط آلومتریک در حوضه‌های آبریز می‌توانند شرایط مختلف سیستم از قبیل تعادل را تعریف کنند. در واقع هر عاملی که سبب شود حوضه از تعادل دور شود ابتدا با تاثیر بر روابط آلومتریک سبب بی‌نظمی در سیستم می‌شود سپس در تعادل سیستم ایجاد مشکل می‌کند و این تغییر می‌تواند توسط مدل‌های آلومتریک فرموله و اثبات شود. در نهایت معادلات آلومتریک می‌توانند ابزار مهمی در پیش‌بینی تحول حوضه‌های آبریز و ارزیابی عملکرد آنها در گذشته و حال شوند.

کلمات کلیدی: آلومتری، حرکات تکتونیکی، حوضه‌های آبریز، حوضه‌های آزمایشی، خصوصیات ریخت سنجی

[Downloaded from ecopersia.modares.ac.ir on 2025-05-18]

[DOR: 20.1001.1.23222700.2017.5.3.2.4]