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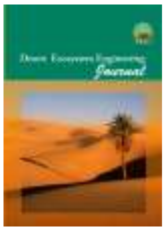

Numerical Analysis of Hydrographic Networks of Pediment Geomorphological Types in Desert Areas Using the Fractal Geometry (Case Study: Yazd-Ardakan Plain, Iran)

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Extended Abstract

Introduction

Quantitative analysis of landform types and geomorphic facies is of particular importance in geomorphological and natural resource studies. In this research, the quantitative characteristics of three pediment landform types—bare pediment, aggradational (appendage) pediment, and covered pediment—were analyzed in the Yazd–Ardakan Plain. The main objective of the study was to elucidate the relationship between these landforms and the geometry and density of the regional hydrographic network. A range of datasets and analytical tools was employed, including Google Earth imagery, a digital elevation model derived from the ALOS PALSAR sensor, and specialized software such as ArcGIS, ArcGIS Pro, and Fractalys. Initially, calculations were performed on randomly selected samples with areas of 1, 4, 9, 16, and 64 km². Based on data analysis in Fractalys software using the box-counting method and variance comparison, a plot size of 9 km² was identified as the optimal sampling unit for calculating the fractal dimension of the hydrographic network in the studied pediment types . Analysis of standard deviation plots indicated that the optimal numbers of sampling plots for bare, aggradational, and covered pediments are 15, 17, and 18, respectively. To validate the results, fractal dimension values from 10 estimated plots were compared with observed values using 9 km² plots for each pediment type. The findings are applicable in quantitative geomorphology, sustainable land management, land-use planning, and geomorphic classification of pediment landforms. Future studies are recommended to investigate relationships between pediment fractal dimensions and hydrological parameters in other Central Iranian plains.

Keywords : Arid lands, Digital Elevation Model, Fractal Dimension Technique, Hydrographic Network, Pediment

Introduction

Analysis of the land surfaces and plains plays a crucial role in natural resource studies. From a geomorphological perspective, landforms are generally classified into three major units: mountains, plains, and playas. Pediment plains are further subdivided into three types: Bare pediment, coalescing pediment and concealed pediment. Traditionally, field surveys, visual interpretation, and boundary delineation using Google Earth have been employed to identify pediment types. In this study, a novel approach based on the fractal geometry technique was applied. According to Mandelbrot, fractal geometry is grounded in objects with self-similar and repetitive patterns across scales. The objective of this research is to apply fractal analysis in order to characterize the

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hydrographic networks of different pediment geomorphological types in desert environments.

Research Methodology

The study area covers 1,441.91 km² in the Yazd-Ardakan plain within Zone 40. satellite imageries from the Advanced Land Observing Satellite ALOS PALSAR were selected through the Earth data Search portal (earthdata.nasa.gov) due to its high-resolution Digital Elevation Model (DEM) capabilities. Using the Hydrology Toolbox in ArcGIS, the hydrographic network was extracted from the DEM. Random plots of varying sizes were selected on the hydrographic network. The Fractalyse software was employed to compute the fractal dimension of plots 1, 4, 9, 16, and 64 km² at a scale of 1:50,000 using the box-counting method. The mean and variance of the fractal dimension across plots in each pediment type were calculated, and diagrams were generated to determine the minimum sampling area.

For validation, 10 observed plots and 10 estimated plots were compared in a 9 km² plot (minimum sample area) in each pediment. The Kolmogorov-Smirnov test and independent t-test were conducted at the 99% confidence level using SPSS software. Model performance was further evaluated using RMSE, Nash-Sutcliffe Efficiency (NSE), Pearson's correlation coefficient (r), scatter plots, regression equations, slope coefficients, and the coefficient of determination (r²).

Results

Table 1. Number and distribution of sampling plots based on size and type of pediment plain

Number of plots in each pediment			Total number of plots	Plot area (km^2)	Plot side length (km)
Concealed pediment	Coalescing pediment	Bare pediment			
55	84	51	190	1	1
34	44	33	111	4	2
20	**22**	**20**	**62**	**9**	**3**
10	12	12	34	16	4
6	5	5	16	64	8

Table 2. Mean fractal dimension of hydrographic networks across plots with different areas.

Concealed pediment	Coalescing pediment	Bare pediment	Plot area (km^2)
1.119	1.178	1.168	1
1.269	1.277	1.273	4
1.363	**1.409**	**1.418**	**9**
1.396	1.409	1.427	16
1.489	1.499	1.508	64

Discussion and conclusion

The point (Turning point of the diagram) at which variance diagrams of fractal dimension become linear and stabilized indicates the minimum sampling area, which in this study was identified as 9 km² plots. From this threshold onwards, the fractal dimension of the hydrographic networks consistently decreased from erosional pediments toward covered pediments. According to the diagrams, the minimum number of samples in the erosional, alluvial fan pediments, and covered pediments is 15, 17, and 18 plots, respectively.

The Kolmogorov-Smirnov test confirmed the normality of the data ($p > 0.05$), while the independent t-test showed no significant differences between observed and estimated data ($p > 0.05$) at the 99% confidence level. RMSE and NSE indices indicated low model error and high predictive accuracy in bare pediment and coalescing pediment. In concealed pediment, RMSE values were close to zero, confirming highly accurate predictions, while NSE also demonstrated acceptable model performance. The results of Pearson's correlation coefficient (r), regression coefficient, and coefficient of determination (r^2) in all three pediments indicate a strong and positive correlation between observed and estimated data and very good model demonstrated performance.

Overall, for 9 km^2 plots—the identified minimum sampling area—the fractal dimensions of bare pediment, coalescing pediment and concealed pediment were 1.418, 1.409, and 1.363, respectively. These results highlight the effectiveness of the fractal geometry technique in geomorphological characterization and hydrographic network analysis in arid regions.