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Channel head morphometry in the precipitation gradient from semi-arid to arid climates

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ABSTRACT

Understanding channel head distribution and its determinants enhances knowledge of drainage system development, but most studies focus on humid climates. Therefore, this study investigates the development of channel heads across a precipitation gradient from semi-arid (370 mm) to arid (90 mm) climates in the Negev Desert, Israel. It focuses on understanding the factors influencing channel head distribution and morphometry, specifically the roles of precipitation and bedrock properties. Based on detailed field measurements of 100 channel heads, morphometric parameters such as local slope gradients above and within channel heads, lengths of headcuts and channel heads bottoms, parameters of the contributing area were analyzed using Principal Components Analysis (PCA) and Analysis of Variance (ANOVA). The results indicated that channel head formation was significantly influenced by both climatic and geological factors. In areas with higher precipitation, channel heads were deeper and more elongated, while areas with erosion-resistant bedrock exhibited larger contributing areas and steeper slopes. The study identified three main factors driving channel head development: the size and shape of contributing areas (primarily affected by bedrock lithology), local slope gradients, and the amount of precipitation. Channel head density, reflecting drainage density, showed a strong negative relationship ($r = -0.69$) with bedrock hardness, a weak relationship ($r = -0.27$ and $r = -0.25$) with frequency of rainfall > 10 mm d^{-1} and erosivity of precipitation, and a very weak relationship ($r = -0.15$) with vegetation cover. The slope-area relationship analysis revealed that channel heads were generally located in the uppermost sections of the valley system in semi-arid climates, while in arid areas, they occurred in both the hillslopes and transition sections of the valley. The study provided crucial insights for land and water management strategies in arid environments, emphasizing the complex interplay between climatic conditions and geological characteristics in shaping the drainage network.

1. Introduction

The location of channel heads and the factors influencing their distribution are key areas of interest for many researchers in the field (e.g. Wohl, 2018 and references therein; Hurst et al., 2019; Płaczkowska et al., 2021; Lessard et al, 2024). Understanding these aspects provides insights into the development of the entire drainage network. The relationship between contributing areas of the channel head and local slopes is commonly used to quantify the occurrence of channel heads (e.g. Montgomery and Dietrich, 1988, 1989; Montgomery and Foufoula-Georgiou, 1993; Wu et al., 2021). Using the slope-area relationship, Iijasz-Vasquez and Bras (1995) distinguished four regions (I-IV) in the hillslope-valley profile in Alabama, USA, each with a different scaling response (different gradient; see Fig. 1 therein): "region I exists where the slope-area scaling has a positive gradient; in region II the gradient turns negative; in region III the gradient, although still a negative value, is much smaller; and in region IV the gradient goes back to a larger negative value". The authors indicated that channel heads occur at the boundary between regions I and II (Iijasz-Vasquez and Bras, 1995). However, studies conducted in various areas worldwide show that channel heads can develop in all regions of the profile (I-IV; Montgomery and Foufoula-Georgiou, 1993; Tarolli and Dalla Fontana, 2009;

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