A multi-method remote sensing study of the morphology and controls of Al-Hajar Mountain alluvial fans, south-east Arabia.

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Fans form where down-system sediment transfers undergo decreases in confinement, such as when confined mountain stream systems enter open sedimentary basins at mountain fronts. Fans represent fundamental buffers in the sediment cascade (e.g. Harvey, 2011), act as palaeohydrological and palaeoenvironmental archives of their mountain catchments (e.g. Parton et al., 2015) and can pose risks to society through flash flooding (e.g. Gutiérrez et al., 1998). The morphometric characteristics of fans are often strongly coupled to catchment morphology. Fan-catchment relationships, therefore, allow the principal controls on fan morphometry, evolution and heterogeneity to be understood, as has been shown in numerous studies of arid region fans (e.g. Stokes and Gomes, 2020). The Al-Hajar Mountains in south-east Arabia represent large, well-preserved fan systems the morphometry of which has been understudied. This is despite the opportunity for unique comparisons of fan morphometric controls, with fans ranging across several orders of magnitude ($10^1$-$10^4$ km$^2$) and terminating in different environments such as the coastline of the Arabian Sea to the east and Rub’al Khali dunefield to the west.

Accurately mapping the extent of the Al-Hajar fans, however, is difficult. This is because they are commonly partly obscured by sand dunes and are becoming increasingly urbanised or disturbed by human activities. To address these issues, we employed multiple remote-sensing datasets to aid the mapping of mountain-front fan systems and their catchments across the Al-Hajar, including Landsat 8 false colour composites, Google Earth historical and modern imagery and spaceborne synthetic aperture radar (SAR). This resulted in the most comprehensive dataset of Al-Hajar mountain-front fan systems produced to date, with c. 400 fans mapped. We then determined numerous morphometric parameters of fans and their catchments. Regression analysis between these variables revealed a significant positive relationship between catchment area and fan area, as well as a significant negative relationship between catchment area and fan gradient, as derived by studies in other arid settings. Analysis of the residuals of these relationships showed that catchment characteristics, such as rock type, as well as base level changes (notably sea level for coastal fans) are important controls on fan morphometry. Comparisons with other arid region fans shows that Al-Hajar fans are both larger and less steep than many other terrestrial fans, potentially making them useful analogues for extra-terrestrial systems.

