Geomorphometric indices over the Drakensberg basalts: Implications for landscape evolution of the Great Escarpment

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Abstract

The application of geomorphometric indices to assess the landscape evolution of active or neo-tectonic regions is well-known. However, using these indices to study the landscape evolution of passive margins is often overlooked. This study uses several established geomorphometric indices to test their applicability in a passive landscape context. The study also provides insights into the landscape evolution of the Drakensberg Escarpment and Lesotho Highlands which together represent a large igneous province composed of basalt. A moving window over a digital elevation model (DEM) with a spatial resolution of 30m was used to derive the following geomorphometric indices: hypsometric integral, surface roughness, relief anomaly, and surface index. Based on the results, highly elevated but low relief regions were identified and mapped, together with areas characterised by high rates of erosion or deposition. With support from data concerning low denudation rates, the indices demonstrate that the undercutting of basalt terraces and the backwearing (retreat) of knickpoints −rather than the downwearing and denudation of basalts − have determined the morphometric shape of the Drakensberg Escarpment.

1. Introduction

The landscape dynamics of active tectonic regions has been assessed using geomorphometric indices based on Digital Elevation Models (DEMs) (e.g., Andreani *et al.*, 2014; Andreani and Gloaguen, 2016). These studies have developed a better understanding of the landscape evolution of active tectonic regions in that they have linked tectonics to surface processes (see Bishop, 2007). However, few geomorphometric indices have been adapted for Passive Continental Margins (PCMs) on tectonically inactive or stable regions. By using multiple geomorphometric methods, (e.g. those devised by Andreani *et al.*, 2014; Andreani and Gloaguen, 2016) derived from DEM analyses, the evolution and nature of the erosion of a PCM, namely the Lesotho Highlands and Drakensberg Escarpment, are investigated. Specifically, the study determines the geomorphometric characteristics of the Lesotho Highlands (above 3000m.a.s.l.) and the Drakensberg Escarpment, as well as the implications of those parameters on the geomorphic evolution of the region.

The Drakensberg Escarpment is an elevated PCM made up of flood basalts that originated roughly 183 million years ago (Duncan *et al.*, 1997). The region has a maximum elevation of 3482m.a.s.l., with the basalts typically extending to 1000m above the underlying sandstones. This region is a portion of southern Africa's Great Escarpment, which developed directly from the breakup and rifting of Gondwana (Tinker, *et al*., 2008; Bregman and Knight, 2022). Importantly, it is assumed that the Great Escarpment has been relatively stable since its formation (Fleming *et al.*, 1999; van der Beek *et al.*, 2002). Several studies, such as Fleming *et al.*, (1999), Brown *et al*. (2002) and Bishop (2007), have investigated the rates of escarpment retreat and the erosion of this geographic feature, which has been used in models of landscape evolution to address various shortcomings in the traditional theories applied to the landscape evolution of PCMs. Notwithstanding advances in landscape evolution models, critical mechanisms regarding the evolution of PCMs, including the Drakensberg Escarpment, are still debated and being questioned (Braun, 2018).

1.1. e Nature of Erosion on Passive Continental Margins

A coastal plain, backed by a steep wall-like escarpment and a plateau inland of the escarpment lip, are the traditional components of a high relief PCM (Bishop, 2007). Such landscapes are associated with a combination of extensional and rifting processes that preceded the continental breakup and post-breakup tectonic processes, and importantly, not the processes associated with active tectonics. Most of the passive margins exhibit slow erosion and longevity, and some even offer proof that they predate the original rifting (Bishop, 2007). Contrary to what the term "passive" implies, the elevation of a PCM needs to be actively maintained or supported; otherwise, the margin would recede or significantly diminish over time − even with low denudation rates (Bishop, 2007). Recent studies that focus on offshore sedimentation and modelling (see Stanley *et al.*, 2021; Gernon *et al.*, 2024) indicate that additional mantle-driven uplift post-rifting is responsible for maintaining a PCM. It has been proposed that there were two separate uplift periods in southern Africa, the most notable of which occurred at 100Ma, as a result of active mantle dynamics (Braun *et al.*, 2014; Stanley *et al.*, 2021; Gernon *et al.*, 2024).

The location of the continental drainage divide affects the types of erosion processes, making it crucial to comprehend how the terrain of the PCM has evolved after continental breakup (Braun, 2018). The escarpment is likely to erode backwards once the drainage divide has been established, or if it has already formed as a pre-existing divide. This process will only halt once the inland catchment regions have been captured. The resultant topography is a steep escarpment wall with topographic highs composed of relict ridges or resistant lithology.[1] The location of the escarpment lip and the pace of retreat are impacted by flexuring isostasy whereby a low stiffness level promotes stability and slows the rate of retreat. Lithological weaknesses, such as dikes, contribute to the formation of the escarpment and are typically thought to be responsible for the distribution of knickpoints and incisions which, amongst others, facilitate the retreat of an escarpment (Braun, 2018). Although Compton *et al.* (2010) suggest that, the Drakensberg Escarpment is maintained and supported by its underlying Karoo sandstones, which yield more resistance to weathering and erosion than the Drakensberg basalts. These contrasting ideas show that substantial uncertainty still exists regarding

[1] The drainage divide in southern Africa was likely pinned to its current location and influenced by the westward tilt of the entire plateau (Braun *et al.*, 2014).

the processes by which PCMs persist for millions of years and at such high elevations (Paul *et al.*, 2014; Green *et al.*, 2018). Thus, more research should be conducted to better understand the geomorphic dynamics of landscape evolution after uplift of PCMs, with the key fingerprints (remnants of erosion) of the landscape change possibly lying in the morphology of the region.

2. Study Area

The Drakensberg Escarpment is part of the Karoo Supergroup, which consists of a range of rocks formed 350-170Mya (Knight, 2019). The upper sections of the Karoo Supergroup comprise a series of sandstone formations, namely the Clarens, Elliot, and Molteno formations. The sandstones are overlain by volcanic basalt outpourings, collectively known as the Drakensberg group (Figure 1). This includes the escarpment edge and summit region, with several of its peaks rising to elevations of over 3400m.a.s.l. The Karoo Supergroup sandstones reach an elevation of roughly 2000m.a.s.l., which forms a lower secondary escarpment and sandstone cliff faces. The entire plateau is slightly westward-tilted, most likely caused by uplift 100Mya (Braun *et al.*, 2014). Dolerite sills and dykes intrude through both the basalt and sandstone formations.

Although, this study focuses on the Drakensberg Escarpment and Lesotho Highlands (both comprising basalts), a larger area boundary was selected for the study area − to incorporate any stand-alone basalt outcrops or *inselbergs* and surrounding sandstone areas into the applied methods to provide the required spatial context. Thus, the eastern boundary of the study area is formed by the minimum elevation contour of 1000m.a.s.l., the western boundary by longitude, 26˚30” E, while the northern and southern boundaries are formed by latitudes 28˚10”and 31˚43” S, respectively (Figure 1).

The Drakensberg Escarpment forms part of a Large Igneous Province and represents a Continental Flood Basalt of 140 000km^2 that covers the Kingdom of Lesotho and South Africa. The total volcanic emplacement resulting in this phenomenon contained 2.5 x 106km^3 of lava which erupted in two separate events of distinct age: the first, approximately 185 Ma, and the second eruption occurring 3 – 5 million years later (Moulin *et al.*, 2011). However, the eruption and emplacement or positioning period for the Drakensberg group and escarpment has been narrowed down by Jourdan *et al.* (2007) to a period ranging from 182.3 ± 1.6 to 181.0 ± 2.0Mya (2σ). The entire geological group can be classified into sub-units (layers) based on observed differences. However, it is worth noting that the chemical composition of these sub-units does not differ significantly from one to the other (Mitchell *et al.*, 1996). For example, in the vicinity of Sani Pass, Mitchell *et al.* (1996) identified a 175m thick layer of chemically heterogeneous basalt overlain by a thick 625m layer (geochemical) of relatively uniform and dense basalt. The basalts comprise a sequence of distinct, shallow horizontal flows, which, on solidifying, subsequently formed terraces (Grab, van Zyl and Mulder, 2005). Sumner *et al.* (2009) indicate that the basalt flows in the northern Lesotho region are as thin as one metre (1m) or can be as thick as 50m, with a mean thickness of approximately six metres (6m) − the median value being 3.2m). The terraces are an important characteristic of the Drakensberg and Lesotho Highlands in that they influence the nature of weathering and erosion in the region and on the escarpment (Grab *et al*., 2005).

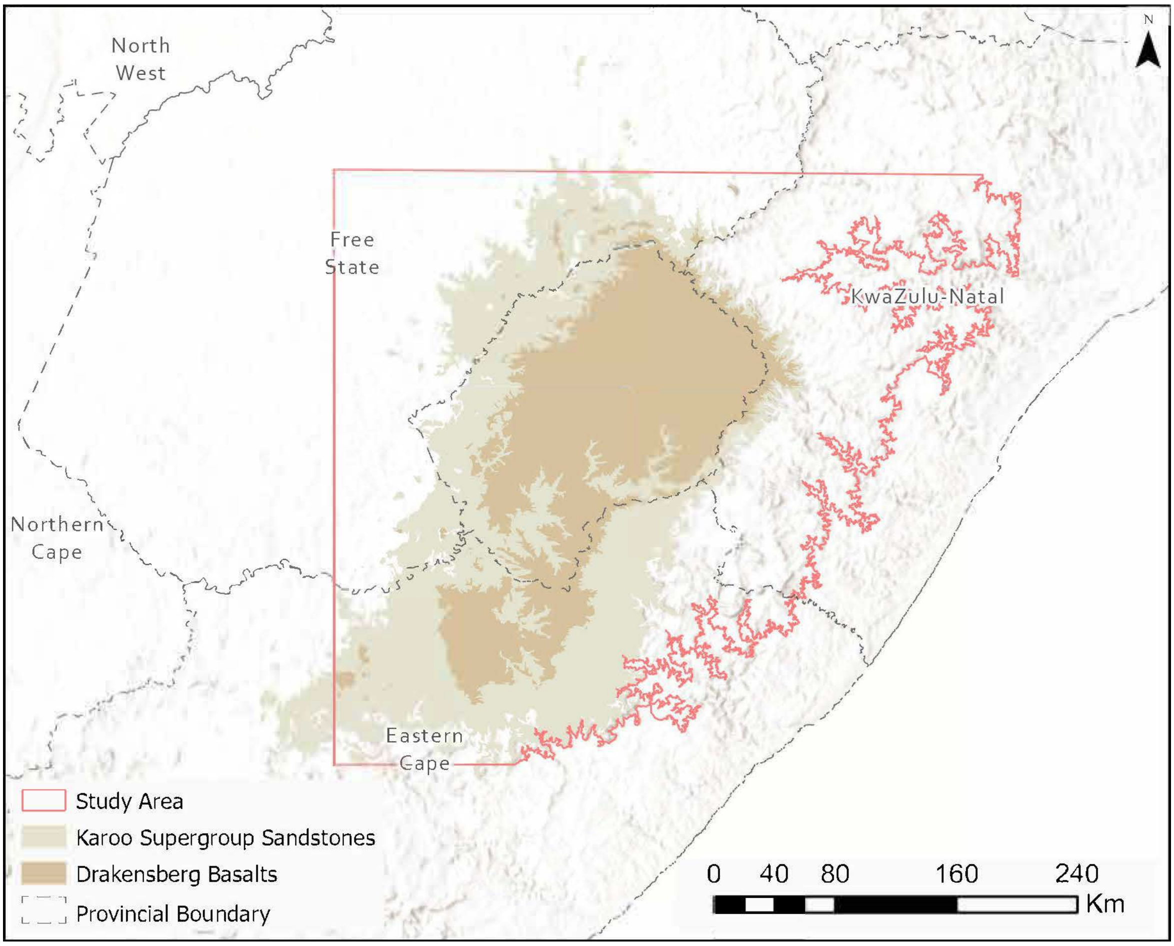

Figure 1. Spatial extent of the study area comprising the Drakensberg basalts group and the Karoo sandstones (Molteno, Eliot, and Clarens Formations).

3. Methodology

The SRTM dataset (30m resolution), with an absolute vertical error of less than 20m (Andreani *et al*., 2014), was used for the geomorphometric analyses in this study. The DEM for the study area was acquired using the SRTM DEM downloader add-on in QGIS 2.28.7. and reprojected into the WGS84 UTM 35S projection by using the Warp tool. The total study area covers an area of 129 699km^2. To derive the geomorphometric indices from the DEM, a 35 × 35 pixel moving window was used to calculate each index. This proved to be effective in smoothing out the localised geomorphometric signatures but in maintaining the large landscape features (Andreani *et al*., 2014).

A combination of geomorphometric indices was used to evaluate landscape evolution over the study area (Figure 1). Traditionally, the established geomorphometric indices (described below) are used to analyse the influence of neo-tectonics over a landscape but, for the first time, they were applied in a PCM context. Specifically, the geomorphometric indices proposed by Andreani *et al.* (2014) and Andreani and Gloaguen (2016), namely the Hypsometric Integral (HI), Relief Anomaly (RA), Surface Roughness (SR), and Surface Index (SI), were used. In particular, the SI, developed by Andreini *et al*. (2014), proved to be helpful in identifying landscapes that are elevated but are subject to low rates of erosion. It is this property that makes this index perfect in the context of landscape evolution for distinguishing between different landscape units within the study area. The study area has not previously been evaluated using these geomorphometric indices and, therefore, this novel data can be used in the context of landscape evolution to review the morphometric properties of the Drakensberg Escarpment and the basalts that underlie the region.

3.1. Relief Anomaly

RA facilitates the interpretation of relief data by representing elevations normalized by the local relief. Therefore, it draws attention to elevated areas within a low local relief area (Andreani *et al.*, 2014; Scotti *et al.*, 2014; Andreani and Gloaguen, 2016; Mathew *et al.*, 2016). Therefore, RA was used to identify any elevated regions in the study area that do not have high incision values. RA is defined by Calculation 1, as indicated below, where, h_{mean} is the mean, h_{min} is the minimum, and h_{max} is the maximum, each calculated over a moving window of 35 x 35 pixels. The mean, minimum, and maximum elevations (h) were calculated using the focal statistics tool in ArcGIS Pro 3.1.3, and with a moving window of 35 x 35 pixels.

$$RA = \frac{h_{mean}}{h_{max} - h_{min}} \qquad [1]$$

Using RA, the study area was categorised into the following three categories, namely, elevated but of low relief, escarpment edges, and eroded basaltic interior. The categories were defined in terms of a visual interpretation of the dataset. Categories that were identified as elevated but of low local relief were noted as highland areas and had RA values over 16.6. Escarpment edges were selected as regions with an RA value smaller than 5.65. Areas with RA values between 5.65 and 16.6 were classified as eroded interior. To avoid water bodies, areas with high RA values but that occur at relatively low elevations were excluded. Different regions were distinguished in terms of their location and distribution over the study area.

3.2. Hypsometric Integral

Hypsometry is used to describe and quantify the relationship between area and altitude at different elevations and can be represented through the hypsometric curve or integral (Pérez-Peña *et al*., 2009). The hypsometric integral (HI) is the ratio of the surface area under the hypsometric curve and illustrates the distribution of surfaces above a basal plain of reference (Andreani and Gloaguen, 2016; Obaid and Allen, 2019). Areas exhibiting a high HI indicate a young topography or land surface where uplift still outpaces erosion (active tectonics), and *vice versa*. HI values greater than 0.5 show convex curves that are indicative of recently rejuvenated relief landscapes. Highly eroded landscapes linked to river erosion processes are indicated by HI values of less than 0.3. In one of the few studies applying HI in southern Africa, Walcott and Summerfield (2008) computed HI for river basins extending from the eastern Drakensberg Escarpment towards the Indian Ocean. They indicated that there is no relationship between the area or form of a basin and its HI value. Rather, their study reveals the intricate relationship between relief, dissection, basin size, and basin morphology. HI in our study was calculated using the raster calculator focal statistics tool in ArcGIS Pro 3.1.3. For a given area, the HI can be calculated by using the following equation (2), where *h* represents elevation, with h_{mean} as the mean, h_{min} as the minimum, and h_{max} as the maximum, each calculated over a moving window of 35 x 35 pixels.

$$HI = \frac{h_{mean} - h_{min}}{h_{max} - h_{min}} \qquad [2]$$

3.3. Surface Roughness

SR is an index which measures the differences between a representation of the true topography of the landscape, as defined by the DEM and a slope map, in relation to a theoretically flat surface of a predetermined elevation. SR values increase rapidly with highly dissected landscapes and can be used to assess the distribution of incisions within a drainage basin and to highlight areas of entrenched rivers below a predetermined baseline of 900m.a.s.l. (following Andreani *et al.*, 2014). The ratio is close to one (1) for flat areas and increases as the topographic surface becomes incised and irregular (Andreani *et al.*, 2014). SR can be determined by applying the equation (3), where *TS* presents the 'topographic surface' and *FS* presents the flat surface of the same extent.

$$SR = \frac{TS}{FS} \qquad [3]$$

Equation (4) was used to calculate the TS (Andreani and Gloaguen, 2016), where *res* is the resolution of the DEM in metres (30m), and α is the pixel value of the slope map in degrees. The slope function in ArcGIS Pro 3.1.3 was used to calculate the slope map in degrees.

$$TS = res + \sqrt{res^2 + (\tan(\alpha) \times res)^2} \qquad [4]$$

FS was calculated by applying equation (5), where *res* is the resolution of the pixel. The flat surface was easily determined by reclassifying the DEM to one value only (900).

$$FS = res \times res \qquad [5]$$

SR was then calculated using the focal statistics tool to summate both the TS and FS through a moving window of 35 x 35 pixels. The purpose of the moving window was to smooth out any localised instances of relief. The resulting raster data files were then used to calculate SR, the latter computed through the raster calculator.

3.4. Surface Index

The Surface Index (SI) shows the distribution of the preserved (original) and eroded surfaces of an elevated landscape by combining relief, HI and SR. SI can highlight both relatively flat landscapes and eroded surfaces on the same map. The function is also sensitive to elevation factors and displays tectonic depressions (Andreani *et al.*, 2014). Therefore, SI allows for the identification of areas with low local relief landscapes from regions with more rugged topography at various altitudes (Andreani and Gloaguen, 2016). Positive SI values are mainly associated with elevated and poorly incised surfaces, the latter being characterised by high HI and low SR values. Negative SI values reflect areas with high SR values −mainly dissected landscapes.

The SI ratio was calculated based on the following equation (6), where *HI* is the Hypsometric Integral, HI_{min} is the minimum, and HI_{max} is the maximum value of the raster. *h* is the elevation (DEM) value, with h_{min} as the minimum elevation and h_{max} as the maximum elevation value of the raster. *SR* is the Surface Roughness value, with SR_{min} as the minimum and SR_{max} as the maximum elevation value of the raster

$$SI = \frac{(HI - HI_{min})}{(HI_{max} - HI_{min})} \times \frac{(h - h_{min})}{(h_{max} - h_{min})} - \frac{(SR - SR_{min})}{(SR_{max} - SR_{min})} \quad [6]$$

4. Results

The results for each of the four geomorphometric indices are shown in Table 1 and Figure 2 (A – D). The RA highlights the valleys and incised river profiles and escarpments. The study area was categorised into different landscape zones/regions (escarpments, highlands, and the eroded basaltic interior) and were separated or differentiated in terms of their location. The regions include the Drakensberg Escarpment (DE), Northwest Escarpment (NWE), South Escarpment (SE), and Southern Drakensberg Escarpment (SDE). The escarpment regions were differentiated in terms of their location and their escarpment aspect. The distribution of higher RA values over the Drakensberg Basalts is one of the primary features of the results. These areas are characterised by high elevations but with low relief variations and low rates of erosion. These were classified as highland areas, with northern Lesotho being the most prominent area. The range of the RA values in these locations exceeds 10, with the following regions being identified: the Eastern Highlands (EH), Northern Highlands (NH), Southeast Highlands (SEH), Southwestern Highlands (SWH), and the Western Highlands (WH). Table 1 shows the average value of each index for the categorised regions.

The HI, displayed in Figure 2, inset B, emphasizes elevated but flat surfaces, as well the escarpment scarps/edges. Typically, tectonic depressions have low values, but higher regions or plateaus with locally-incised features have high values (Andreani *et al.*, 2014). The mean Hypsometric value over the entire study area falls within the young-but-eroding phase, with minimum and maximum values of 0.008 and 0.937, respectively. The Lesotho Highlands (above 3000m.a.s.l.) exhibits a smooth transition from HI values close to one (1) to almost 0 (zero) along the incised rivers. The ridges are highlighted with HI values over 0.5, and the main rivers are below 0.3. These details differ from the sandstones found west of the basalts of the Drakensberg where several mesas, buttes, and *inselkops* are present. Such landforms have a similar shape to escarpments and are also highlighted by the HI, with values over 0.7 at the cliff face that decline to below 0.3 in a single step.

Table 1: Average value of indices over each region. Regions: DE – Drakensberg Escarpment, NEW – Northwest Escarpment, SE −South Escarpment, SDE – Southern Drakensberg Escarpment, ESI – East and Southern Basalt Interior, EH – Eastern Highlands, NH – Northern Highlands, SEH – Southeast Highlands, SWH – Southwestern Highlands, WH – Western Highlands.

	Elevation	RA	HI	SR	SI
DE	2227.91	4.405754	0.473328	1.177372	-0.16488
NWE	2276.737	4.82416	0.454409	1.138077	-0.10297
SE	2039.891	4.758826	0.460413	1.116696	-0.11321
SDE	2195.824	4.811612	0.46631	1.133258	-0.10647
ESI	2209.967	8.566193	0.471064	1.060974	0.020995
EH	3017.577	18.56867	0.462226	1.028102	0.238427
NH	3040.238	17.84136	0.494738	1.026989	0.272142
SEH	2131.881	19.62049	0.476871	1.018366	0.074716
SWH	1836.269	21.12838	0.480226	1.012335	0.021249
WH	2638.246	16.7216	0.522285	1.030347	0.198887

Typically, the basalt formations in the interior of Lesotho have values that are either around or greater than 1, indicating a relatively smooth or flat surface. The highest SR values over the study region are seen along and below the northern escarpment. This implies that as opposed to its adjacent areas, the region has experienced notable erosion or incision. Nonetheless, there are comparatively flat surfaces or plateaus adjacent to the northeastern and southern escarpments. Poorly incised surfaces, which have a high HI and a low SR, typically show positive SI values. Negative SI values will represent locations with high SR values and can primarily be attributed to dissected landscapes (Andreani *et al.*, 2014). Very low SI values occur over the escarpment, whereas larger values apply to the escarpment lip. The 'flat' highland surfaces are clearly shown in Figure 2 (d) and are differentiated into the northern, southern and western regions of Lesotho. The region adjacent to the amphitheatre (Figure 3, inset A) exhibits elevated SI values compared to the interior of the Drakensberg basalts and the remainder of the Lesotho Highlands. Consequently, this elevated zone appears to be less incised. The SI detects high elevation changes between valley ridges and valley floors deep within the flood basalts. Typically, the ridges have values close to or above 0, while the valley floors have very low values, below 0. Every index effectively highlights the escarpment edge, which forms distinctive boundaries between the basalts and sandstones. However, the escarpments in the northern Drakensberg exhibit the largest outputs of erosional effects and rates. Immediately surrounding the Drakensberg basalts are the Karoo Sandstones, which show low RA values, which increase further toward the edge of the dataset. Relatively flat regions, identified by low RA and high SI values, and with low SR values, are clearly highlighted in the south-eastern and north-eastern portions of the Drakensberg Escarpment.

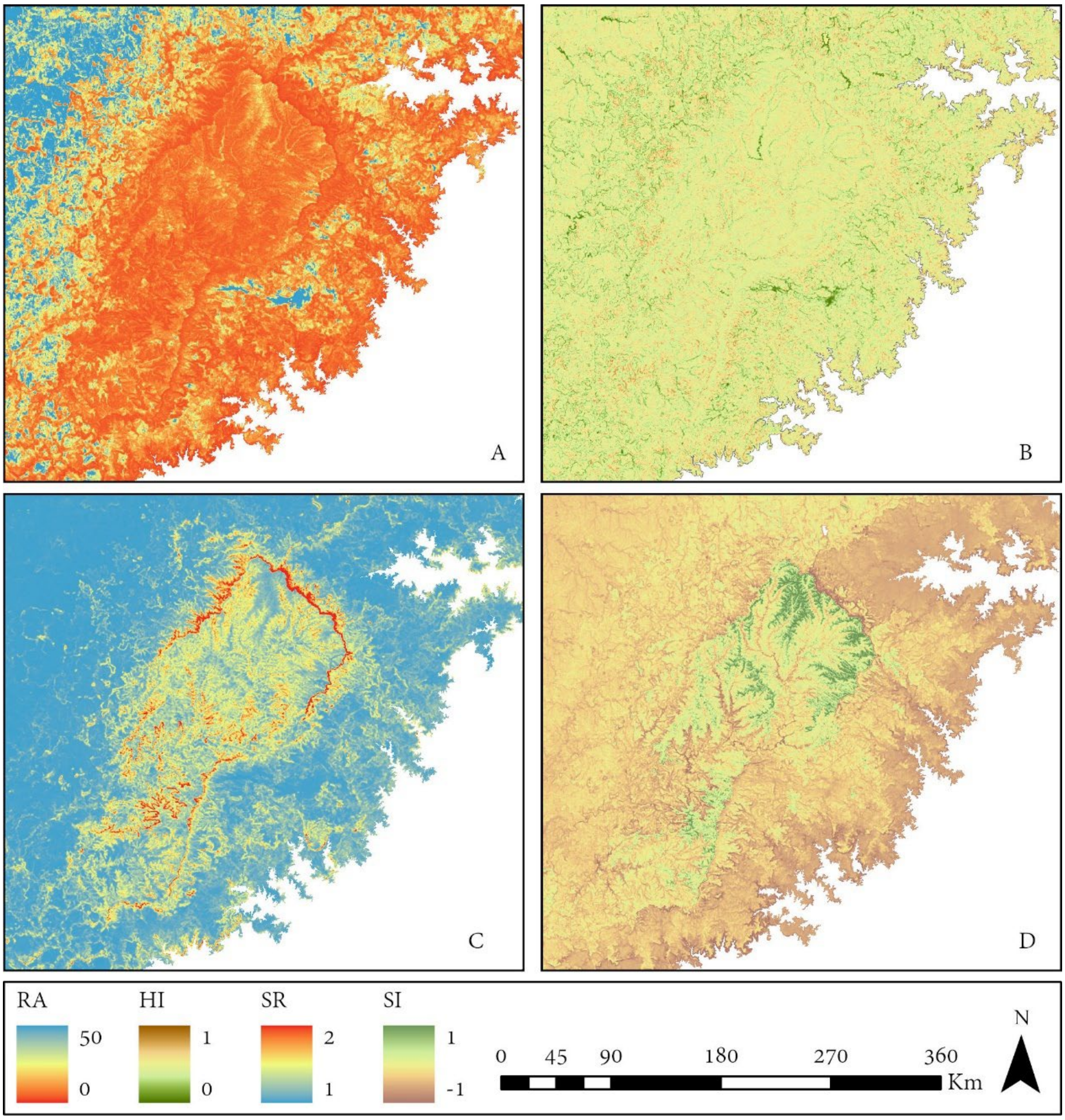

Figure 2. Distribution of the (a) RA, (b) HI, (c) SR, and (d) SI over the study area. The border of Lesotho is not included so as not to obscure geomorphometric features such as the escarpment edge.

5. Discussion

The geomorphometric indices show that there are two significant regions of low local relief over the study area. The first is on the elevated, relatively horizontal, basalt plateau. The second area lies below 2000m.a.s.l., in the Karoo Sandstones. In contrast, areas of high local relief change, suggesting active erosion and incision, occur in the altitudinal and geological transition zones between the Lesotho Highlands (above 3000m.a.s.l.) and the lower sandstone surfaces and over the escarpment edge. Five elevated but preserved surfaces, namely, H1 – H5, were identified in Figure 3. The most significant (H1), in northern Lesotho, encapsulates Mount-Aux-Source, the source of the eastward-flowing Tugela River and the westward-flowing Senqu River. Elevated regions have RA values over 16.6. Escarpments are identified as regions with an RA value smaller than 5.65, with a total of four zones being identified (E1 -E4, Figure 3). The highland areas have very low erosion rates, especially in northern Lesotho. They receive little rainfall and typically have very gentle slopes (Braun *et al.*, 2014), low SR values, and a combination of low SR values and high SI values. The decrease in the size of the area and the disjointed and differentiated characteristics of the elevated surfaces in the west of Lesotho suggest that this region has experienced faster rates of denudation and incision as opposed to the eastern elevated regions which flank the Great Escarpment.

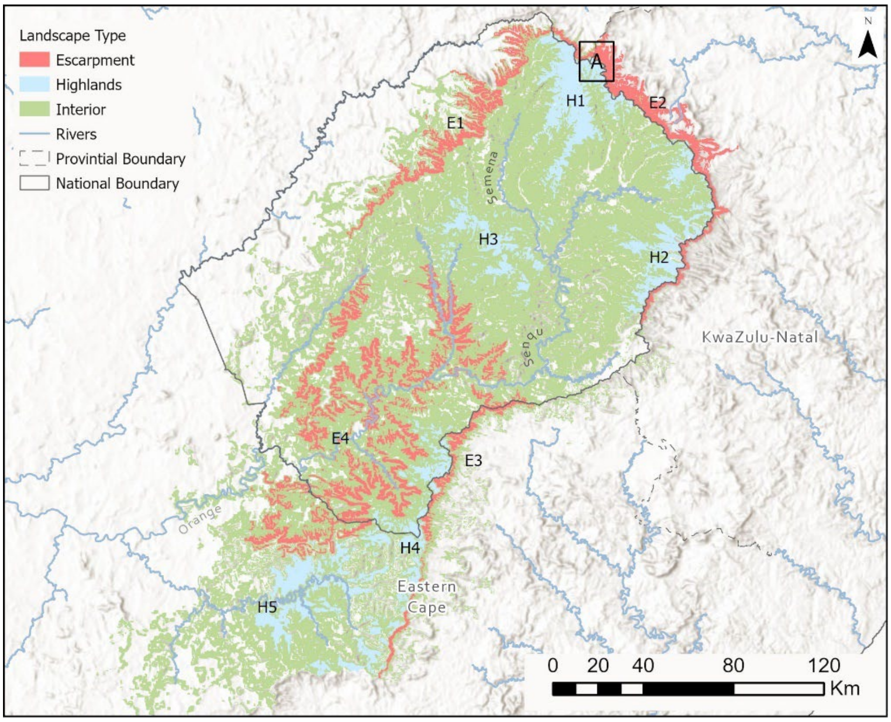

Figure 3. Distribution of landscape types identified over the Drakensberg basalts. Inset A represents the location of the Amphitheatre, which showcases the highest erosion rates; H1 – H5 indicate the five distinct highland landscapes; and E1-E4 indicate the escarpment zones.

5.1. Implications for the Evolution of the Lesotho Highlands and Plateau

The formation of the Drakensberg Escarpment and Lesotho Highlands is characterised by a series of dynamic events spanning millions of years. At around 183 ± 1 Ma, during the Jurassic period, the region experienced significant volcanic activity, which coincided with the tectonic breakup of Gondwana and was marked by the eruption of flood basalts. At least 400m of basaltic rock has been removed since its emplacement (Dunlevey *et al.*, 1993). Concurrently with the outpouring and breakup of Gondwana, dolerite intrusions occurred throughout the area, adding to the geological complexity of the region. These intrusions contributed to the formation of distinctive geological features within the Drakensberg −either through the exposure of zones of preferential weathering or through the formation of a cap that protects the underlying material. The remaining elevated surfaces of the high Drakensberg and the upper reaches of the Drakensberg basalts exhibit low denudation rates which have been primarily influenced by supply-limited weathering (Chen *et al.*, 2020). Two regions, namely, H4 and H5, do not have the same elevations as the highland areas located north of the Senqu River, as presented in Figure 3. These elevated surfaces are at an elevation of 2000m.a.s.l., which is much lower compared to the H1, H2, and H3 which are situated at or above 3000m.a.s.l. The highland areas are relatively flat with small variations in topographic relief and low rates of denudation, although chemical weathering can occur quickly once a new surface has been exposed (Chen *et al.*, 2020). Thus, the Lesotho Highlands appear to have a stable terrain in terms of the low variability of their landscape indices.

The indices demonstrate that the undercutting of basalt terraces and the backwearing of knickpoints, as opposed to the downwearing and denudation of the basalts, are the primary drivers of landscape change. Both the SR and SI data demonstrate that the removal of basaltic material is a lateral process, which has accelerated from the West. They point to significant erosion along the escarpments and basaltic terraces that border the highland areas. According to Grab *et al*. (2005), the current slope retreat does not appear to be dependent on rapid mass-movement events that occur suddenly, since the near-vertical scarp faces appear to be in equilibrium with the erosional processes. The SI results corroborate another observation made by Grab *et al*. (2005): − The rock surfaces around the peak and scarp have been exposed for a longer period than those near the base of the scarp. A secondary phase of uplift in the region (Baby *et al.*, 2020) would accelerate knickpoint development and backwearing into the Drakensberg basalts and the underlying sandstones. The incision- making process would be rejuvenated, leading the tributaries in the area to widen the valleys down to the more resistant sandstone and mudstone layers, specifically in the Elliot Formation (Compton *et al.*, 2010). The duration of the rejuvenation process would last until the drainage basins adjust to the new base level. The results of this study indicate that the north-eastern region of Lesotho is the least affected in that they showcase only the most prominent elevated surfaces. It is, therefore, suggested that despite a secondary increase in elevation of the flood basalts at roughly 30Ma, higher elevations do not necessarily correlate with higher denudation rates, even if the erosion rates along the margins have increased.

6. Conclusion

Four geomorphometric indices were calculated to analyse the terrain surface of a passive continental margin, namely the Drakensberg Escarpment. The geomorphometric indices used to measure landscape dynamics in the region show that areas below the northeastern escarpment are currently experiencing the highest rates of erosion. However, areas within the Lesotho Highlands are classified as areas of low relief, with low erosion and incision rates, and interspersed between landscapes predominantly characterized by steep eroded scarps and valleys. Based on the results, five such highland areas were identified. This suggests that, with the support of low denudation and erosion rates in the region (Fleming *et al.*, 1999), backwearing into the basalts is a key factor in landscape change in the region. Since the indices are not typically used in the context of a PCM, the further development of geomorphometric indices and their refinement are necessary to effectively assess landscape evolution by determining the distribution and dynamics of long-term erosion.

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