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Using Texture Statistics to Identify and Map Different Dune Types within the Rub' al Khali

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Abstract: Understanding the movement, direction, and shape of sand dunes can contribute to reducing their impact on infrastructure and the environment. The Rub' al Khali desert has a distribution of dune types. This study aims to identify and map the different types of dunes within the Rub' al Khali using a texture analysis method based on a digital elevation model (DEM). Statistical texture analysis methods (variance, skewness, and kurtosis) show three different textures of sand dune shapes, according to the geography of the dunes, using data contained in global DEMs. The analysis presented in this study focused on the use of DEMs to investigate the varied dune morphology within the Rub' al Khali. The GMTED2010 and EarthEnv_DEM90 digital elevation models were compared. Spatial variability in dune height, spatial variability in dune texture, and profile graphs were created to examine dune surfaces in cross-section. The results provided six different dune types within the sand sea: giant compound linear dunes, simple linear dunes, simple transverse dunes, compound crescentic dunes (megabarchans), huge star dunes, and many transitional forms that defy classification. The results showed that the compound linear dune and simple linear dune were the dominant dune types, covering 41.61% and 31.7% of the total study area, respectively. The maps of variance, using either 10 × 10 and 30 × 30 focal blocks, produced a fairly sharp distinction in dune texture. It is hoped that future research in aeolian geomorphology will greatly benefit from these results, which could easily be expanded with the use of more sophisticated pattern recognition software, which clearly shows the value of using such an approach.

Keywords: Rub' al Khali; sand dunes; dune types; texture analysis; DEM

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1. Introduction

The Rub' al Khali is the largest and perhaps most significant sand sea in the world. Over the years, the dunes remained largely unexplored owing to the harsh climate and hostile terrain. More recently, our understanding of this desert has been greatly enhanced by the comprehensive work of [1,2]. Distinguishing sand dune types in the Rub' al Khali desert in terms of their shape and formation is difficult. The sand dune patterns in the Rub' al Khali desert reveal different dune types. Many researchers have focused on the different dune types in the Rub' al Khali, but they have classified the dunes using different methods, which makes it difficult to compare the results. Most of the early research on dune morphology classified the dunes based on field observations and air photo interpretation [1,3,4]. Many studies have taken advantage of the analytical capabilities inherent in geographic information systems (GIS) and remote sensing [5]. Later research classified and mapped the dunes using Landsat imagery [5–7]. The distribution of different dune types was developed by [3], who classified five sand dune forms in Saudi Arabia based on field work and the analysis of aerial photographs. These include transverse sand dunes in the northern region of the Rub' al Khali, vegetated dunes, linear dunes, giant dunes, and hooked dunes. To aid in the interpretation of Landsat imagery, [8] developed a classification system based on five main dune types (linear, crescentic, star, parabolic, and dome-like), with each main class subdivided into three forms (simple, compound, and complex). Simple dunes are generally smaller isolated mounds or ridges of sand with similar-sized slipfaces. Compound dunes, in contrast, are very large dunes characterized by the extensive development of secondary sets of slipfaces on the main dune form. Lastly, complex dunes are a combination of two or more different dune types. Abdelsamie et al. [9] identified three of the main dune types (linear, crescentic, and star), and each main type was further subdivided into more descriptive classes. For linear dunes, the subclasses include simple and short, mostly simple with some compound, compound feathered, compound with two sets superimposed, and complex with start dunes superimposed. For crescentic dunes, the subclasses include simple barchanoid ridges, compound barchanoid ridges, compound discontinuous barchanoid ridges, compound barchans, complex reversing ridges, complex ridges with star dunes superimposed, and complex ridges with linear elements superimposed. For star dunes, the subclasses include simple, some compound, and compound in sinuous chains. Edgell [1] presented 16 sand dune types found in the Rub' al Khali desert: giant linear dunes, transverse dunes, crescent dunes, barchanoid dunes, megabarchan, plumate, convergent, dome, pyramidal, parabolic, barchans, barchanoid ridge, draa ('uruq or linear), seif, small linear dune, sigmoidal dune, and hooked dune. According to [10], Bramkamp arranged the dunes into four classes: (i) Transverse sand dunes are simple and compound banchan dunes, the shape of which is based on the direction of the wind. (ii) Longitudinal sand dunes have diverse shapes of linear dunes and wind direction has a role in their formation. (iii) 'Uruq dunes are a diverse type of linear dune, a closely parallel type found near valleys. (iv) Sand mountains have complex crescents, separated in the east of the Rub' al Khali desert. Digital geomorphological mapping (DGM) is crucial for enhancing our knowledge of the Earth's physical features, geological history, natural resource management, hazard assessment, and landscape evolution. By utilizing remote sensing and geographic information technology, DGM collects, analyzes, and visualizes data, benefiting diverse scientific fields and practical applications [11–13].

Several recent studies have used geospatial technology to analyze dunes, but they have focused on eastern [14] data from the Shuttle Radar Topography Mission (SRTM) and Landsat TM imagery to study the megabarchanoid dunes of the Rub' al Khali in Al Liwa in the United Arab Emirates (UAE). To describe the dunes, [15] used a nearest neighbor analysis to examine the degree of self-organization, which might be related to the relative age of the dunes. In [16], dunes in the southeastern region of the Rub' al Khali in Saudi Arabia were studied using Google Earth Pro, Landsat imagery, and SRTM data. Mapping spatial variations in dune morphology across the entire dune field is complicated by two factors. First, many dune forms transition from one type to another. Although the boundaries between two different types of sand dunes are remarkably distinct, in other cases, the types of dunes overlap with each other and have fuzzy boundaries [17]. Second, there is no widely accepted universal classification system for sand dunes and without an unambiguous ontology, defining the type of dune and the boundaries associated with that dune type becomes very difficult [18]. Given these two constraints, this analysis focused on mapping only the major classes of dunes that are widely recognized in the literature. Moreover, it is important to note that the boundaries associated with each dune type are somewhat subjective as most dunes transition from one type to another type.

The aim of this study is to identify and map the different types of dunes within the Rub' al Khali based upon an analysis of digital elevation models (DEMs) using texture analysis methods. This study uses an analysis of dune texture and then evaluates the results through a visual interpretation of different dune types based on shaded relief and performs an analysis of the profile graphs.

2. Materials & Methods

2.1. Study Area

The Rub' al Khali is the largest sand sea in the Arabian Desert, with a variety of very large dune forms; it is the largest continuous sand sea in the world and is located in the southern part of the Arabian Desert's southern margin, extending into parts of western Oman and northern Yemen [5]. It occupies the surface of a large sedimentary basin between the mountains of the Arabian Shield to the west, the Hadramawt–Dhofar Arch in the south, and the Al Hajar (Oman Mountains) and Arabian Gulf in the east; these are shown in Figure 1. The boundary of the sand sea closely follows the boundary mapped by [2]. The geography of the Rub' al Khali in the southern Arabian Peninsula has a dune–interdune area of about 520,000 km^2 and an overall total area of about 660,000 km^2 [1].

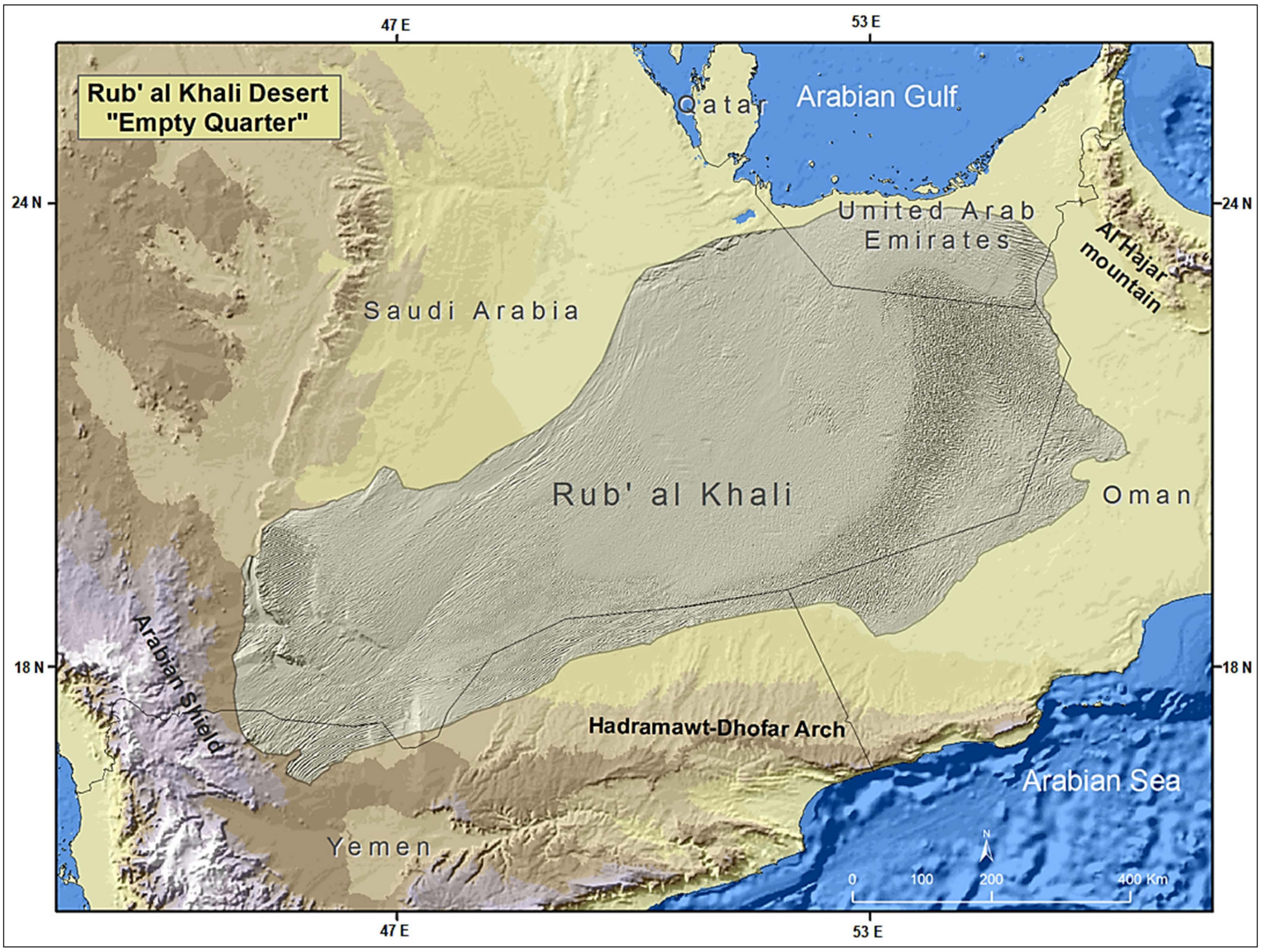

Figure 1. Location and regional setting of the Rub' al Khali on the Arabian Peninsula.

The Rub' al Khali has a distribution of different dune types, making it difficult to distinguish the shape of the dunes. Figure 2 shows the different types classified into six categories loosely following the system proposed by [8]. The six dune types include (1) complex linear dunes, (2) compound linear dunes, (3) simple linear dunes, (4) star dunes, (5) simple transverse dunes, and (6) compound crescentic dunes.

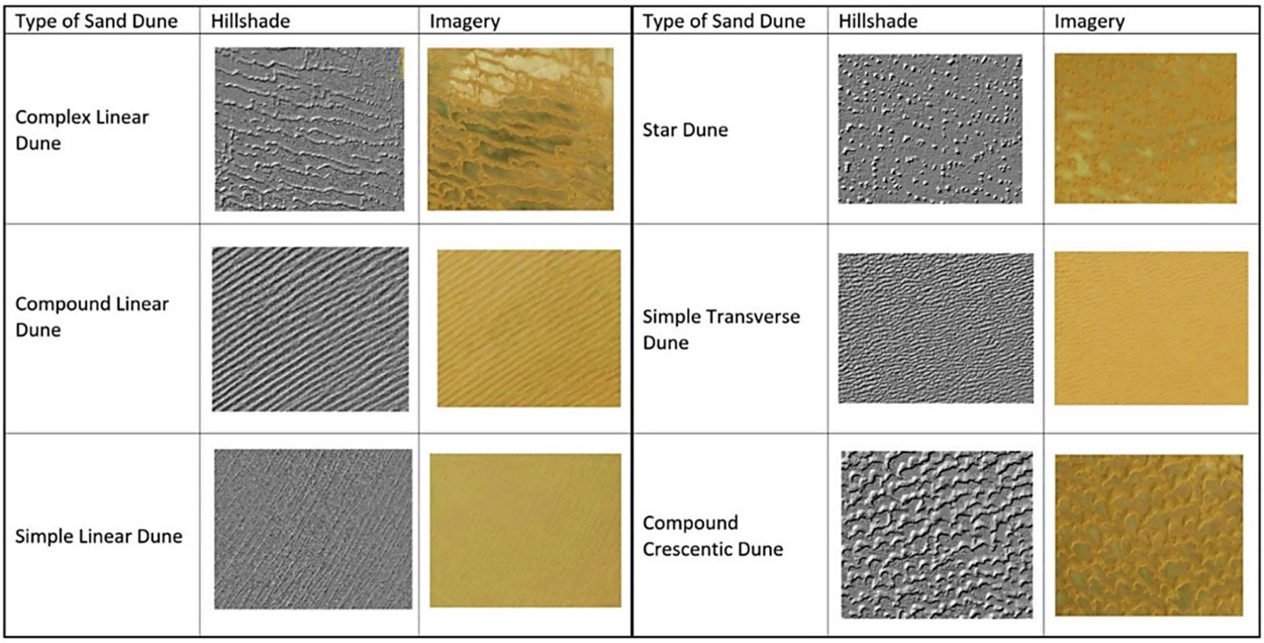

Figure 2. The types of sand dunes in the Rub' al Khali desert determined from satellite imagery and shaded relief.

2.2. Data Sources

The data sources are DEMs, which provide detailed information about the elevation of terrain, although they have not been widely used in the analysis of dune environments [19–21]. The analysis presented in this study is focused on the use of DEMs to investigate the varied dune morphology within the Rub' al Khali. Filling surface depressions in DEMs were simultaneously determined to estimate the missing values within the DEM file according to [22].

DEMs GMTED2010 and EarthEnv_DEM90 were compared. EarthEnv_DEM90 is a relatively new, high-quality, near-global, void-filled DEM developed from fused ASTER and SRTM data [23]. In addition, the data are available at a spatial resolution of 3 arcseconds (~90 m). GMTED2010 is the Global Multi-resolution Terrain Elevation Dataset developed by the U.S. Geological Survey and the National Geospatial Intelligence Agency as a replacement for GTOPO30. This global DEM is derived from 11 different raster data sources, although the primary source is resampled SRTM data. The data are available at three different spatial resolutions: 30 arcseconds (~900 m), 15 arcseconds (~450 m), and 7.5 arcseconds (~225 m). Because the elevation data are resampled from higher-resolution data sources, each of the three datasets is available as a product suite developed using different aggregation methods: minimum elevation, maximum elevation, mean elevation, median elevation standard deviation of elevation, systematic subsample, and breakline emphasis. Table 1 shows the spatial resolution of the two global or near-global DEMs that are currently available and widely used for terrain analysis. Each of the DEMs was developed from different sources and each has a different spatial resolution.

Table 1. Digital elevation models used for terrain analysis.

DEM Name	Original Source	Resolution	Year	Source Link
GMTED2010 v2	Shuttle Radar Topography Mission (primary source)	Multi-resolution, 30, 15, and 7.5 arcseconds	2011	https://topotools.cr.usgs.gov/gmted_viewer/viewer.htm, accessed on 22 March 2022
EarthEnv-DEM90	Derived by fusing ASTER GDEM v2 with SRTM v4.1	3 arcseconds (~90 m)	2014	http://www.earthenv.org/DEM, accessed on 22 March 2022

2.3. Proposed Methods to Distinguish Sand Dune Types

The method of dune texture analysis explores the concept of using texture statistics to identify and map different dune textures within the Rub' al Khali. The different types of dunes within the Rub' al Khali were classified and mapped using visual interpretation. The patterns or textures associated with linear dunes, simple transverse dunes, compound crescentic dunes, and star dunes are very different, and each type of dune has a unique signature in shaded relief. While these markedly different dune patterns are readily apparent to the human eye, it is not clear whether these patterns can be quantified in a meaningful way and related to different types of dune morphology. According to [24], we recognize texture when we see it, but it is very difficult to define.

To analyze the data contained in raster elevation models, ERDAS IMAGINE (Hexagon Geospatial) and ArcGIS (Esri) provided a number of standard geoprocessing and analytical tools. In each analysis presented here, the elevation data were downloaded as tiles to cover the spatial extent of the Rub' al Khali. These tiles were then mosaicked and clipped to the boundary of the Rub' al Khali. The polygon used to clip the elevation rasters closely follows the area defined by [2].

Once the DEMs were mosaicked and clipped to the boundary of the Rub' al Khali, the DEMs were analyzed using (1) the Texture tool in ERDAS IMAGINE, to analyze dune texture; (2) the Hillshade tool in ArcGIS, to create a shaded relief map; and (3) the Profile Graph tool in ArcGIS, to create and analyze transects across the dune field. In each case, the DEMs were analyzed using the original unprojected data with reference to the WGS 84 datum. In this way, the resampling that occurs when rasters are projected did not modify the values of the original data. Only when the analysis was complete was the data frame projected for final display.

Texture analysis measures the level and type of texture within a moving window that has been passed over a DEM or other continuous raster image. Texture analysis can be used to identify the feature characteristics of objects or regions in an image [25]. Texture classification is advantageous in a variety of applications due to its ability to disengage the spatial variation in pixel intensity. In addition, image texture is the recognition of image regions using texture properties [26]. While most pattern recognition software is designed to be used with multiband satellite imagery, this analysis of dune texture was focused on the use of a single band DEM. To analyze dune texture, two different DEMs were used, each with a different spatial resolution. The first DEM used in the analysis was EarthEnv-DEM90, which has a spatial resolution of 3 arcseconds (~90 m). The second DEM used in the analysis was the 30-arcsecond version (~1 km) of GMETD2010. To examine the differences in dune texture, both DEMs were analyzed using the texture tool in ERDAS IMAGINE to map the variance, skewness, and kurtosis of elevation values. Variance is the square of the standard deviation, which describes the frequency distribution of values around the mean.

A low variance indicates that elevation values are similar and a high variance indicates a wide range in elevation values. In contrast, skewness is a measure of symmetry in the frequency–distribution curve relative to the mean. Skewness equals zero if the frequency distribution of elevation values is symmetrical about the mean and either positive or negative depending on whether the frequency–distribution curve is skewed above or below the mean. Kurtosis is a measure of the flatness or sharpness of the peak in a frequency–distribution curve, relative to a normal distribution [27,28]. Positive kurtosis indicates a narrow-tailed, peaked distribution of elevation values and negative kurtosis indicates a flatter, heavy-tailed distribution.

To calculate each of the three texture statistics, two different neighborhoods were used to define the matrix of the moving window (or focal block) passing over each DEM. In the first case, a 10 $\times$ 10 cell focal block was used. For EarthEnv-DEM90, this translates into an area of about 900 m $\times$ 900 m. For the GMTED2010 DEM, this translates into an area of about 10 km $\times$ 10 km. In the second case, a 30 $\times$ 30 focal block was used. For EarthEnv-DEM90, this translates into an area of about 2700 m × 2700 m. For the GMTED2010 DEM, this translates into an area of about 30 km × 30 km.

The Hillshade algorithm calculates a shade value for each grid cell based on the altitude (45) and azimuth (315) of the illumination source and the values of terrain slope and aspect. Shaded relief helps to identify, classify, and map spatial variability in dune morphology; therefore, it is important to use a high-resolution DEM that captures the details of dune morphology. To create the shaded relief map of the dune field from the DEM data, the DEM was processed using the Hillshade tool available in ArcGIS (Esri). The raster produced from the DEM had grid-cell integer values ranging between 0 and 255. When these Hillshade values were symbolized using a grayscale color ramp, the raster appeared as a shaded relief visualization of the terrain [29].

The Profile Graph tool in the 3D Analyst extension to ArcGIS can be used to extract a graphical representation of one or many profiles from a DEM. In this analysis, transect profiles are used to examine the change in the elevation of the dune surface and relate this profile to the dune texture. The profile graphs were created using GMTED2010 30-arcsecond (~1 km) elevation data. To produce a more detailed description of dune morphology, 13 profile graphs were created across the Rub′ al Khali desert in different zones. Figure 3 shows the location of each profile transect across the dune field, from northwest to southeast. The procedure steps of this method are shown in Figure 4 to help explain how it works.

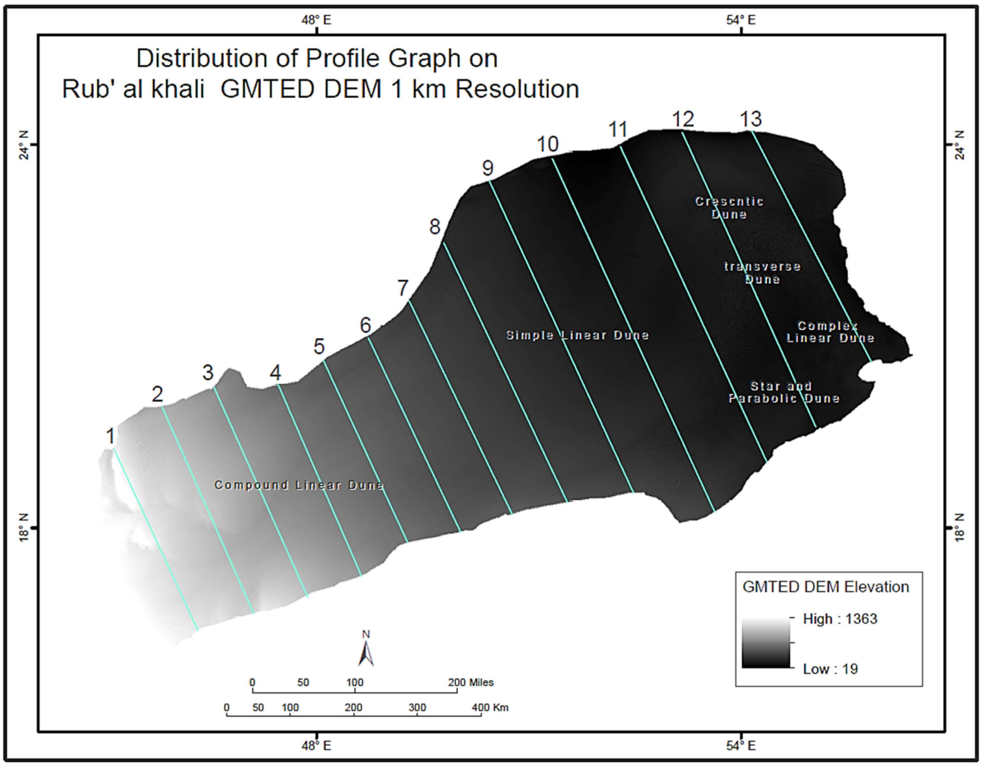

Figure 3. 13 profile graphs were created through across the Rub′ al Khali desert in different zones, from northwest to southeast.

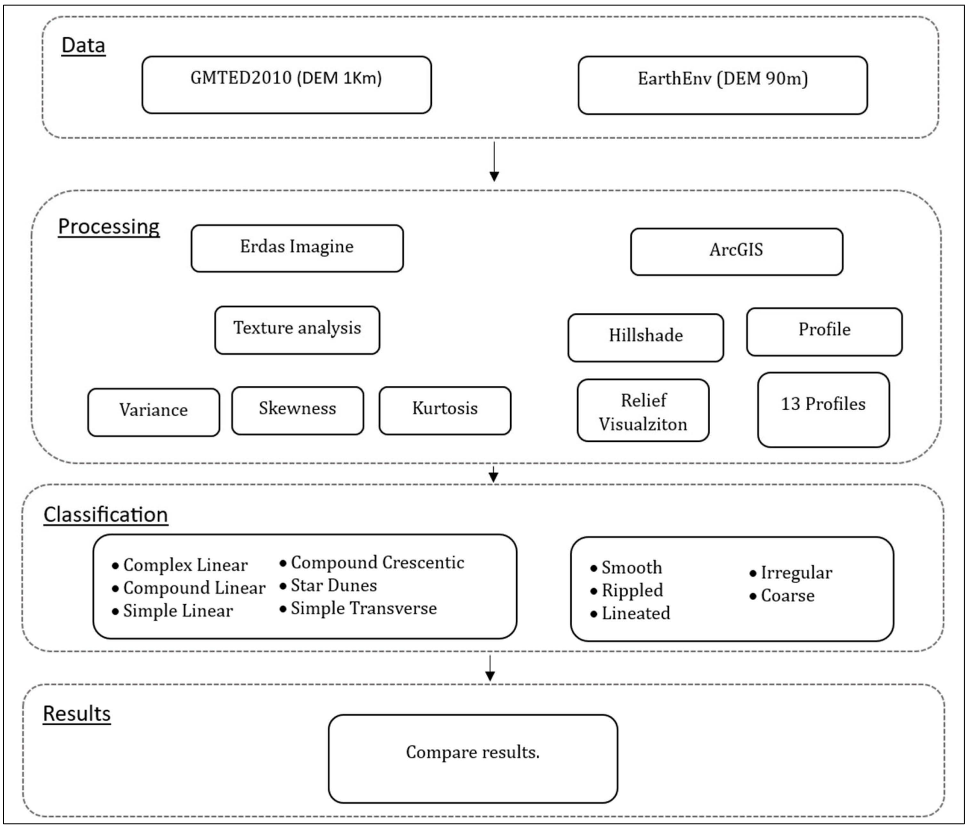

Figure 4. Flowchart of the method to identify different sand dune types.

3. Results

In this study, geospatial technology was used to identify, classify, and map spatial variability in dune morphology within the Rub' al Khali. The analysis focused on an analysis of DEMs to capture the spatial variability of sand dunes by creating a map of shaded relief, a map of dune height, a map of dune texture, and profile graphs across the dune field. Figure 5 shows the results of the analysis of 1 arcsecond (~30 m) EarthEnv-DEM90 elevation data using 10 × 10 and 30 × 30 focal blocks. Examining the six maps, the three that used a 10 × 10 focal block produce a more speckled appearance (A, B, and C) compared with the three others that used a 30 × 30 focal block (D, E and F). The larger size of the 30 × 30 neighborhood includes more cells in the statistical calculation (100 cells vs. 900 cells) over a large area, which leads to a better definition of different textures. Moreover, while each of the statistics (variance, skewness, and kurtosis) provide some definition of different textures, the map of variance provides the clearest definition.

In a similar manner, Figure 6 compares the results of the analysis of 30 arcsecond (~1 km) GMTED2010 elevation data, again using 10 × 10 and 30 × 30 focal blocks. As might be expected, the maps produced using a 10 × 10 focal block contain more detail (A, B, and C) and the maps produced using a 30 × 30 focal block are more generalized. In this case, however, the two maps of kurtosis (C and F) provide little definition of different dune textures in the central and western part of the dune field. Similarly, the two maps of skewness (B and E) are difficult to interpret, although skewness seems to highlight the transition between different dune forms. As before, the best definition of the different dune textures is produced using the variance statistic on a large focal block. Both of the maps of variance, using either 10 × 10 or 30 × 30 focal blocks, produce a fairly sharp distinction in dune texture.

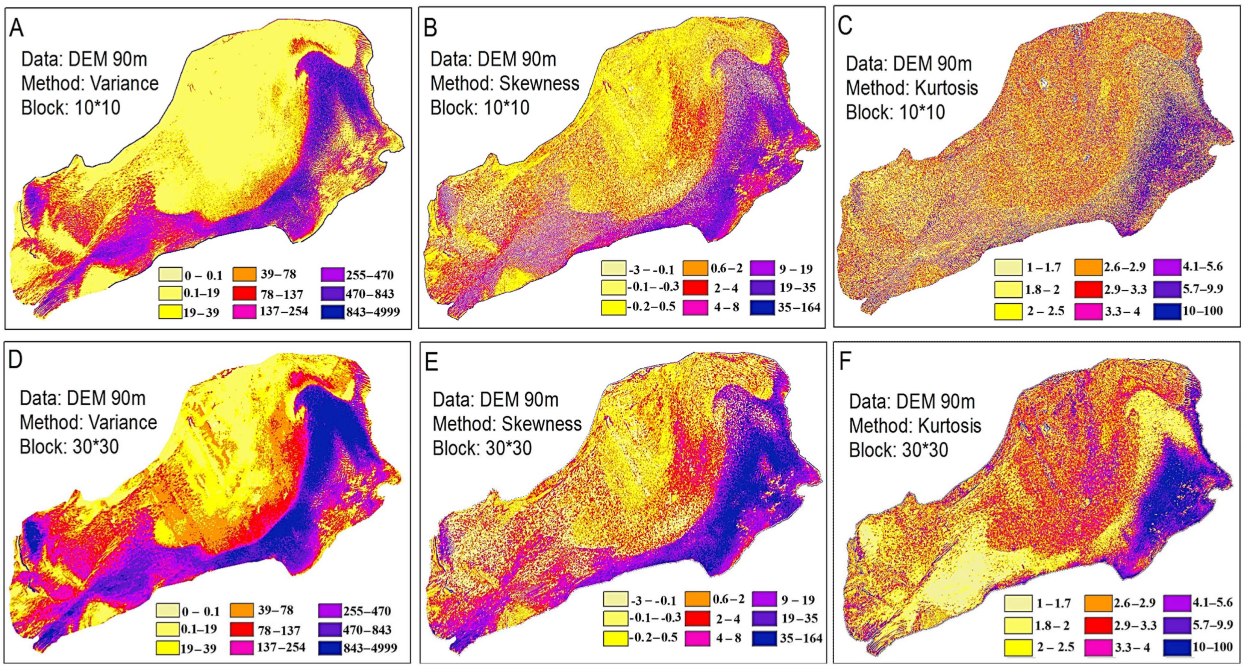

Figure 5. Texture analysis of the Rub' al Khali using EarthEnv-DEM90 with variance, skewness, and kurtosis within a moving window using 10 × 10 for (**A**–**C**) and 30 × 30 blocks for (**D**–**F**).

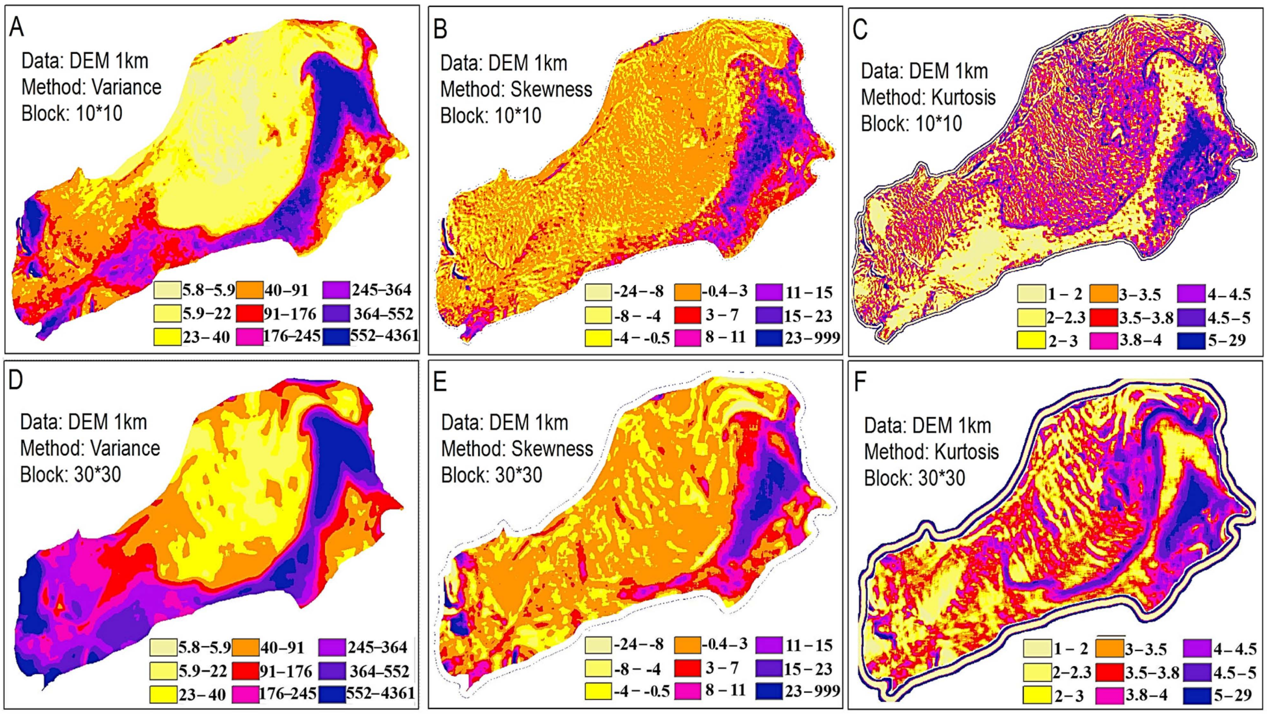

Figure 6. Texture analysis of the Rub' al Khali using GMTED2010 1 km with variance, skewness, and kurtosis within a moving window using 10 × 10 for (**A**–**C**) and 30 × 30 blocks for (**D**–**F**).

Figure 7 shows the results of the visual interpretation using shaded relief to identify and map the six different types of dunes within the Rub' al Khali. Very large compound linear dunes are found in the western part of the Rub' al Khali. Simple linear dunes are concentrated in the center of the dune field. Complex linear dunes occur on the eastern edge of the dune field. Simple transverse dunes are found in the northeastern part of the dune field. Compound crescentic dunes (or megabarchans) are found in the eastern area of the Rub' al Khali. These large compound crescentic dunes then transition to large linear chains of star dunes, with many large, isolated star dunes scattered in the south of the eastern part of the Rub' al Khali.

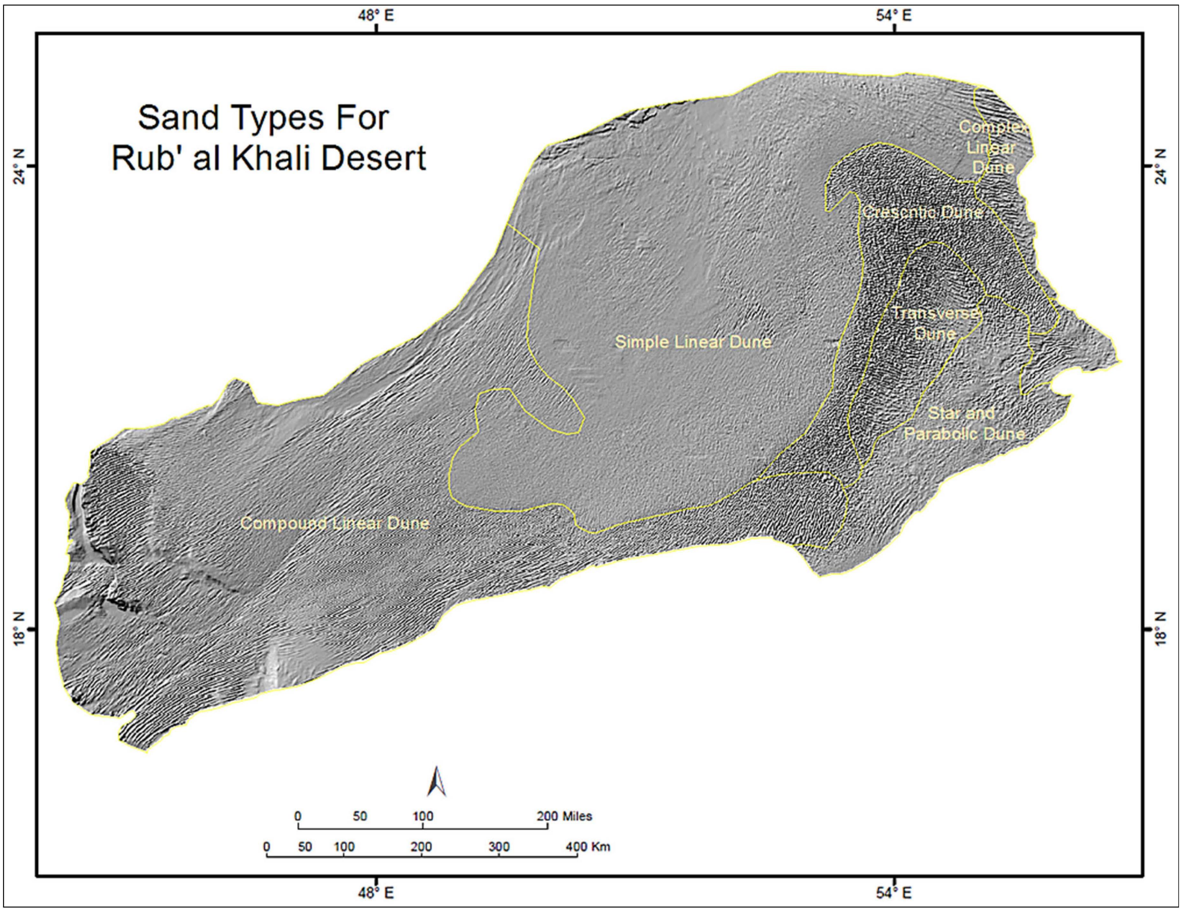

Figure 7. Visual classification of dunes using shaded relief.

Figure 8 shows each of the surface profiles of the dunes, classified as either smooth, rippled, lineated, irregular, or coarse, based on the variance in dune elevation mapped earlier in Figure 8. The wave form of the profiles represents differences in dune morphology, and the topography of the wavelength and height are associated with different textural categories. The largest dunes with the largest wavelength, those with a coarse texture, are associated with linear dunes in the western part of the dune field (Profile 1) and the compound crescentic (megabarchans) and linear dunes in the eastern part of the dune field (Profiles 12 and 13). Profile 1 also shows the lineated texture associated with the smaller (but still quite large) linear dunes that occur in the lower elevations of the large wadi.

Moving eastward from Profile 1 to Profile 4, the largest linear dunes with a coarse texture transition to moderately sized linear dunes with a lineated texture. From Profile 4 to Profile 7, the lineated texture class covers a smaller area and shifts toward the south, giving way to the emergence of the rippled texture class. Similarly, Profiles 7 to 10 show that the rippled texture class gives way to a smooth texture surface. This smooth texture classification corresponds to the simple linear and simple transverse dunes in the center part of the dune field. Concurrently, Profiles 7 to 10 also capture the larger dunes on the southern margin of the dune field as lineated and irregular textures. Continuing to move eastward, Profiles 10 to 13 have a variety of different dune textures. Moving from Profile 10 to 12, an irregular and then coarse texture emerges as the dunes become larger, and Profile 13 contains some very large dunes. Interestingly, these very large dunes in Profile

13 do not all fall into the same texture class. Some are classified as coarse, while others are classified as irregular and lineated.

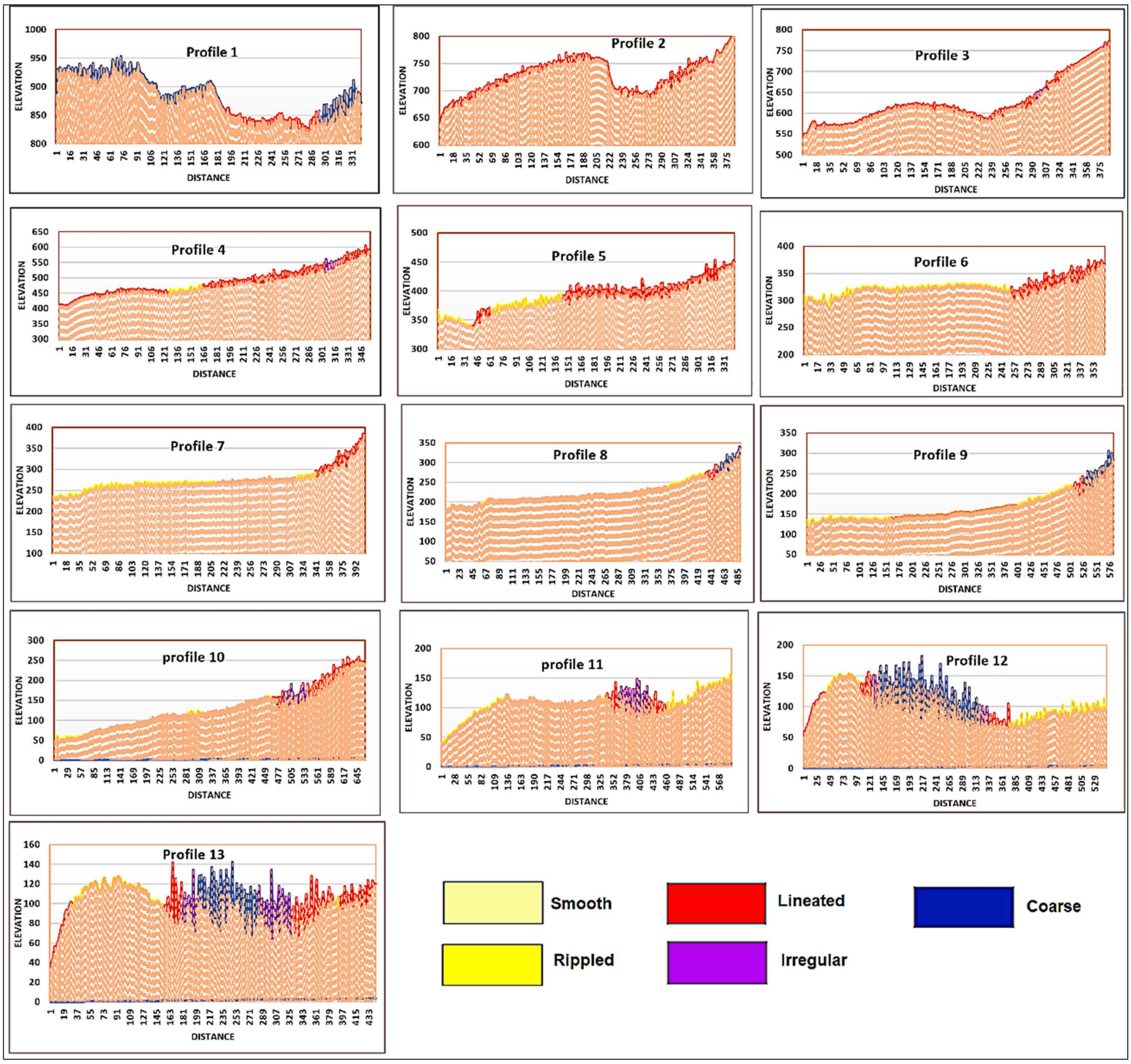

Figure 8. The profiles of sand dune elevation (smooth, rippled, lineated, irregular, or coarse) according to texture classification.

4. Discussion

While the results of this analysis are very encouraging, there is obviously uncertainty in any GIS analysis [30]. In this regard, the visual interpretation of different dune forms is somewhat subjective and the boundary between these different dune forms is often fuzzy. Similarly, the classification of dune texture based on variance in elevation (or any other statistical measure) will depend upon the spatial resolution of the data, the size of the neighborhood, the number of classes, and the breakpoints in that classification. Despite this uncertainty in the analysis, there should be at least some relationship between the classification of dune types based on shaded relief and the classification of the different dune textures. Figure 9 shows a classified version of the variance in dune elevation that was shown previously in Figure 8. This is the output of the texture analysis of the GMTED2010 30 arcsecond (~1 km) DEM using the 30 × 30 focal block with five classes. In this map, the texture is classified as either being smooth, rippled, lineated, irregular, or coarse [24].

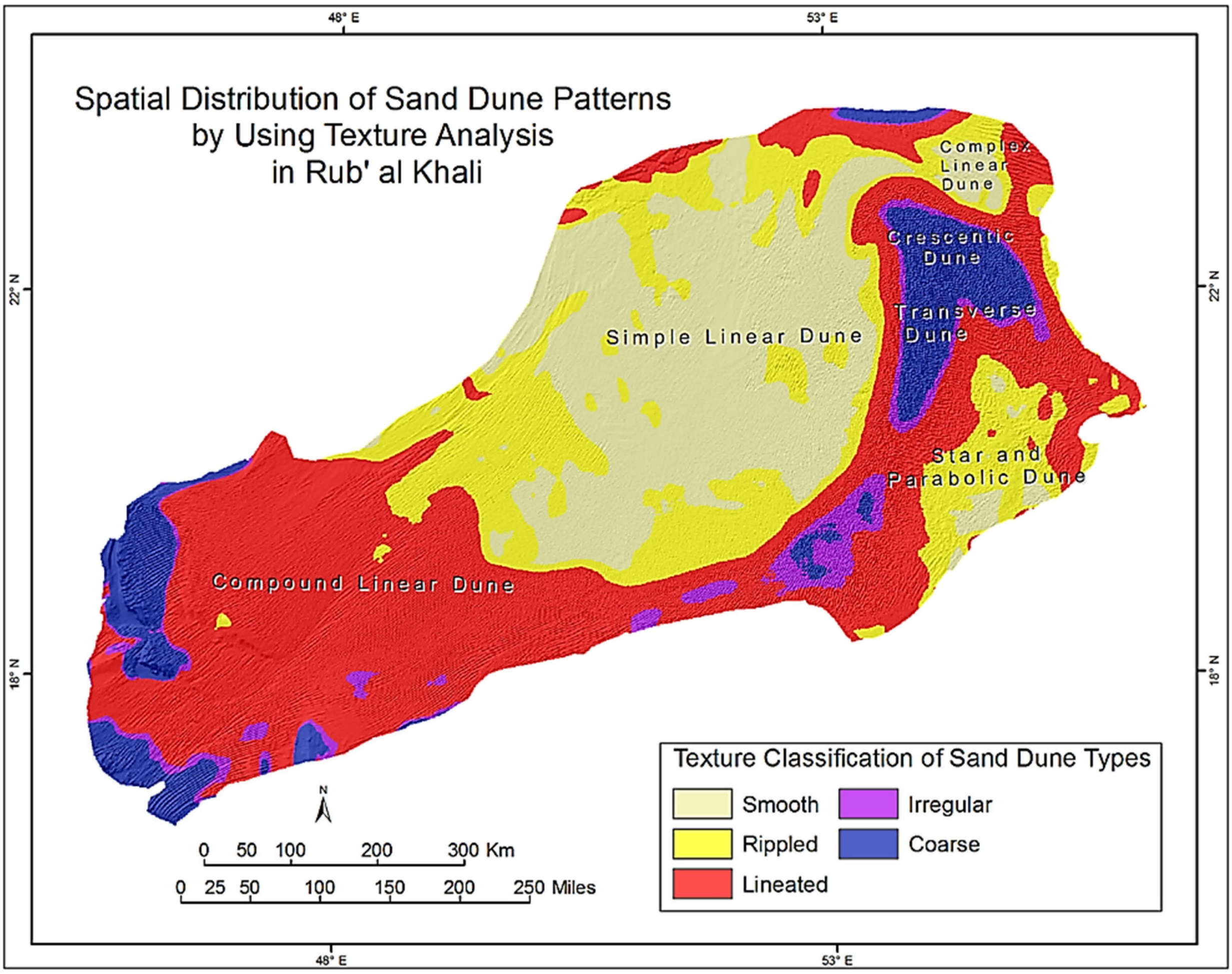

Figure 9. Texture classification using GMTED2010 DEM 1 km with variance using 30 × 30 blocks. Results are classified into smooth, rippled, lineated, irregular, or coarse categories.

Figure 10 provides a summary of the approach used here to illustrate how geospatial technology can be used to identify different types of dunes. The top row shows an example of large compound linear dunes with a lineated texture classification. In general, compound linear sand dunes have a height ranging between 45 and 80 m, except for a small part on the northwestern edge of the Rub' al Khali where they become very large. In the northwestern part of the dune field, compound linear dunes can reach 150 m in height with a spacing of 1.5–2 km. The second row shows much smaller simple linear and simple transverse dunes with a smooth texture classification. These simple linear dunes occur mostly in the central part of the dune field, where they reach heights of the order of 10 to 25 m with a small spacing of between 200 and 300 m. The third row shows large compound crescentic dunes (megabarchans) with a coarse texture. These dunes are among the largest in the dune field; they are about 3 to 4 km wide and reach a height between 100 and 260 m. Lastly, the fourth row shows very large star dunes with a rippled texture. These star dunes can occur as isolated dunes or as a linear chain of dunes. They are also among the largest in the dune field, reaching heights of over 200 m. The spacing between star dunes varies, but many have spacing of the order of 1 to 3 km.

It might be possible to use different geotechnical methods in order to assess the spatial variabilities and spatial patterns in the accuracy of the mapping of the Rub' al Khali desert and identify areas with large uncertainty. Wind plays a prominent role in the formation of the Arabian deserts, whether in their erosion, transportation, or deposition [31]. To explore this idea, the area of each dune type was compared to the area of each dune texture. Using the Union tool in ArcGIS, the overlay analysis created a new feature class by combining these features in the dune classification layer with the features in the texture analysis layer. Table 2 and Figure 11 show the results of this analysis, expressed here as percentage of total area. Complex linear dunes mostly have a lineated texture (69%). Compound linear dunes mostly have a lineated texture (66%). Simple linear dunes are much smaller dunes found generally in the center of the dune field. These simple linear dunes are mostly associated with a smooth texture (62%). The area of large compound crescentic dunes (or megabarchans) is classified mostly as a coarse texture (55%). Star dunes are largely associated with either a rippled texture (49%) or lineated texture (43%). Lastly, simple transverse dunes are largely associated with a smooth texture (47%). Determining the types of sand dunes and their characteristics can be useful to determining ways to protect the surrounding environment and reduce the impact of agricultural activities and promote sustainable soil management [32–34].

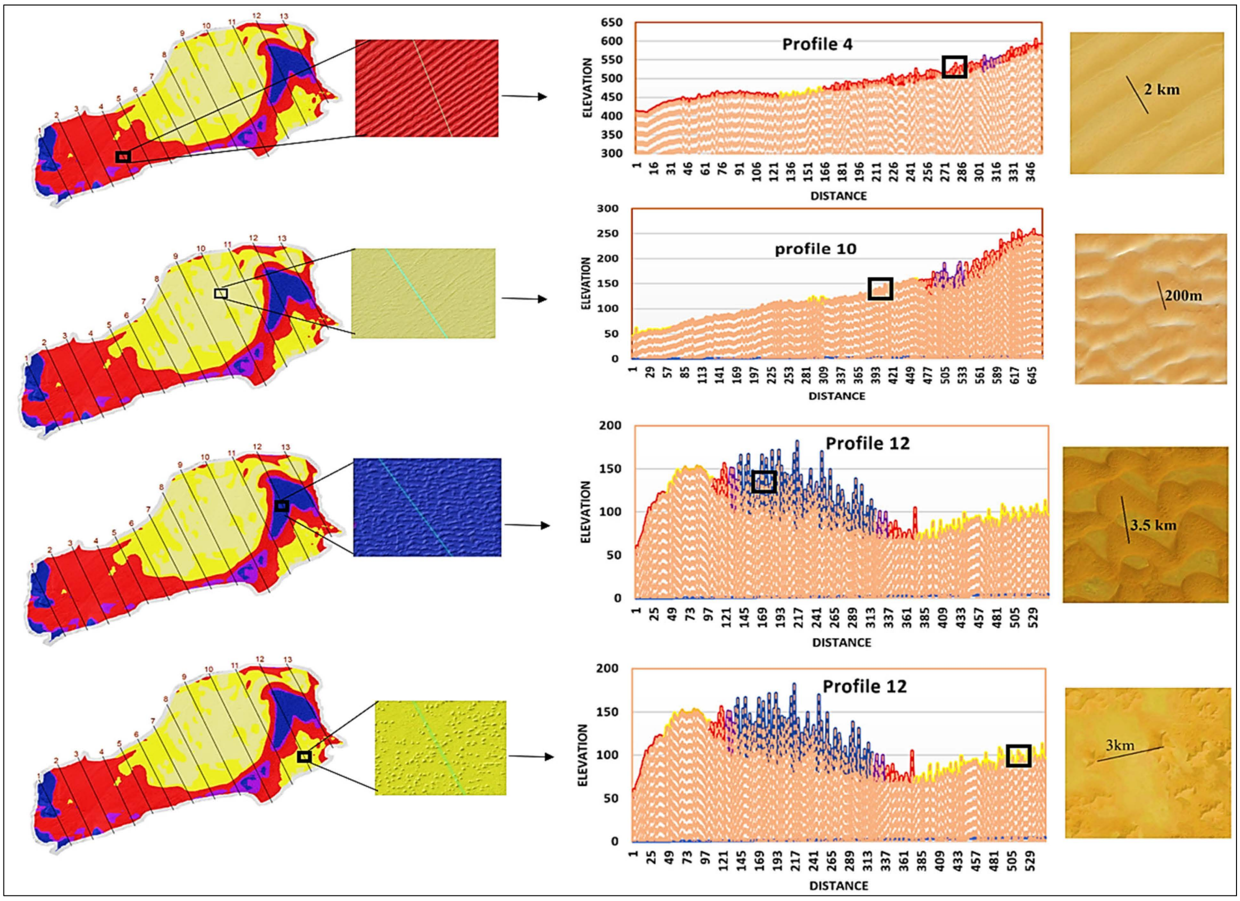

Figure 10. Measurement distinction between dune forms with analysis of texture, shaded relief, and profiles of dune morphology.

Table 2. Comparison of percentage of total area between texture analysis and visual classification.

Categories	Smooth	Rippled	Lineated	Irregular	Coarse	Total %
Complex Linear Dunes	0	31	69	0	0	100
Compound Linear Dunes	3	14	66	2	15	100
Simple Linear Dunes	62	30	7	0	1	100
Compound Crescentic Dunes	0	1	39	5	55	100
Star Dunes	8	49	43	0	0	100
Simple Transverse Dunes	47	38	16	0	0	100

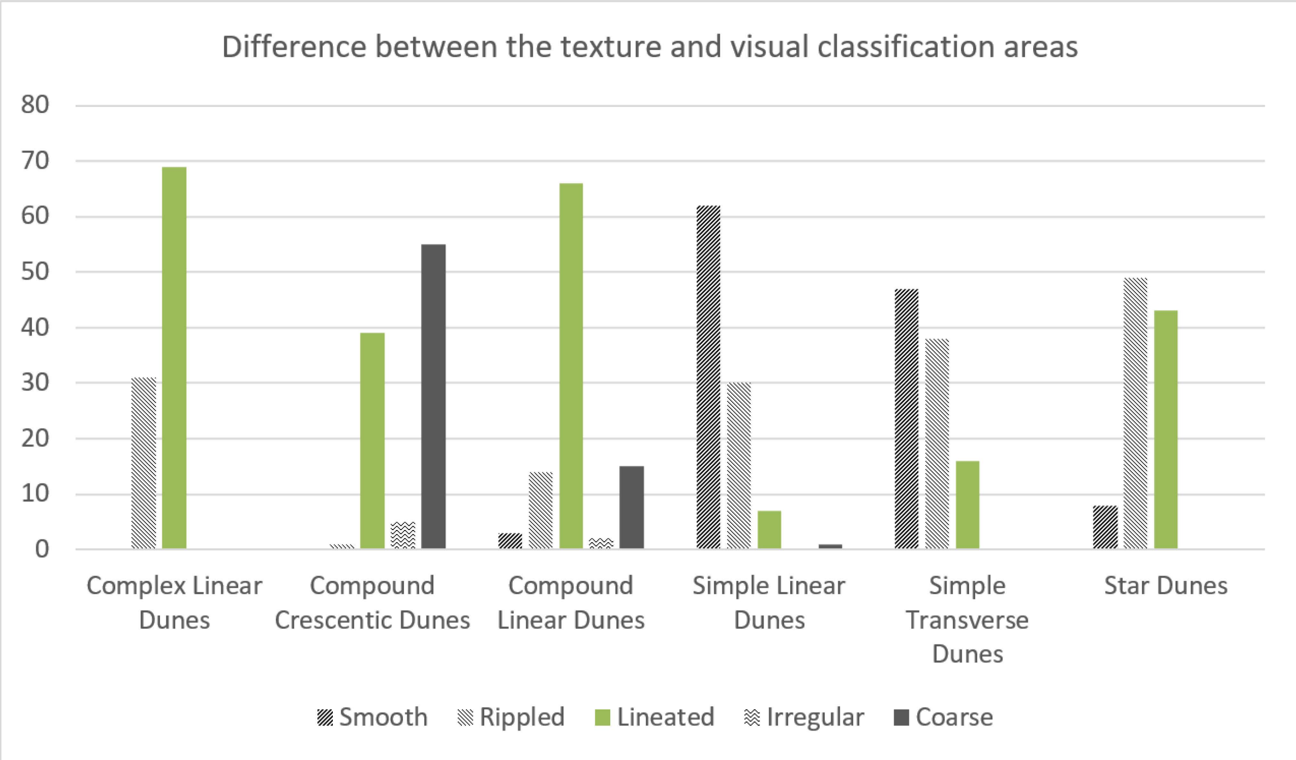

Figure 11. Differences between texture analysis and visual classification results.

5. Conclusions

This research focused on texture analysis methods, specifically statistics such as variance, skewness, and kurtosis, to define various textures of sand dunes. This study revealed insights into the geography of these dunes and demonstrated the effectiveness of texture analysis in detecting sand dune patterns within the Rub' al Khali desert, even when some overlap occurs among dune forms. The sand sea comprises a range of dune types, including giant compound linear dunes, simple linear dunes, simple transverse dunes, compound crescentic dunes (megabarchans), huge star dunes, and transitional forms that defy classification. These dunes also vary significantly in size, with the largest dunes reaching over 250 m, as determined through the analysis of profile graphs.

Moreover, this study introduced novel methods and analytical techniques. This research proposed using texture statistics to map the spatial variability in dune height from a DEM and applying texture analysis to map the spatial variability in dune surface patterns. The variance maps, utilizing 10 × 10 and 30 × 30 focal blocks, sharply distinguished dune textures.

The results indicated that simple linear dunes occur predominantly in the central part of the dune field, reaching heights of approximately 10 to 25 m and spaced roughly 200 to 300 m apart. These simple linear dunes are mostly associated with a smooth texture (62%) among the total sand dune shapes.

Furthermore, the findings revealed that the largest dunes, characterized by a coarse texture, are located in the western part of the dune field, along with compound crescentic (megabarchans) and linear dunes in the eastern part. The large compound crescentic dunes are primarily classified as having a coarse texture (55%), whereas smaller linear dunes at lower elevations exhibit a lineated texture. The largest linear dunes with a coarse texture gradually transition to moderately-sized linear dunes with a lineated texture, whereas complex linear dunes mostly exhibit a lineated texture (69%). This smooth texture classification aligns with the presence of simple linear and simple transverse dunes in the central part of the dune field, with simple transverse dunes being largely associated with a smooth texture (47%).

This study demonstrates how geospatial technology can effectively identify different types of dunes, particularly when focusing on large compound linear dunes with a lineated texture. Compound linear sand dunes typically range from 45 to 80 m in height, although in a small part of the northwestern edge of the Rub' al Khali they can become exceptionally large, reaching heights of up to 150 m with a spacing of 1.5 to 2 km. Additionally, this research highlights very large star dunes with a rippled texture, which can appear as isolated dunes or form linear chains. These star dunes are predominantly associated with a rippled texture (49%).

This study emphasizes that even with straightforward texture statistics, the results can be expanded with the use of more advanced pattern recognition software. This underscores the potential value of such an approach in future aeolian geomorphology research, promising significant benefits for the field.

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