Geomorphologic Features Characteristic of the Rabigh Coastal Area of the Eastern Red Sea, Saudi Arabia, Using Field Studies and Sentinel 2 Imagery

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Abstract. The study undertakes an investigation of the coastal landforms along the Rabigh coastal zone on the eastern side of the Red Sea coastal plain, as well as the processes responsible for the existing landforms on the coast. The landforms occurring in coastal areas are diverse, encompassing sandy shores, tidal zones, sand dunes, sabkhas (salt flats) and marshes, raised coral reef terraces, beach rocks, lagoons, fringing reefs, terrigenous materials and alluvial deposits. These landforms indicate that the conditions on such beaches have undergone rapid change. Various natural land covers were distinguished by subjecting Sentinel 2 data to digital image processing techniques. The findings obtained through this method were then validated through fieldwork. Supervised classification was especially effective in differentiating fringing reef, which is red in colour, from reef limestone, which is brown in colour. Moreover, the supervised classification imaging indicated wadi drainage and estuary systems in a number of areas, specifically on the south side of the Al Kharrar lagoon, into which the Rabigh and Al Hablis wadis drain. The generated images clearly reveal how various landforms are distributed. The findings produced are valuable as a foundation, not only for future geological, engineering and hydrological research but also for governmental decision-making.

Keywords: Coral reef terraces, Sentinel 2 data, Supervised classification, Geomorphological features, Sabkha, Saudi Arabia.

1. Introduction

Various morphogenic factors contribute to coastal landform shape, such as geology, environmental factors like wind and waves, which in turn are determined by climate, and weathering processes causing the breakdown of coastal rock outcrops (Bird, 2000; Carter, 1991; Pethick, 1984). Coastal processes include the after-effects of tidal rise and fall as well as related tidal currents (Birds, 2000). Sea temperature and salinity are among the oceanographic factors affecting those processes and they are in turn dependent on climate and ocean current patterns. Furthermore, the manner in which littoral sediments are distributed and transported is affected by the geomorphology, lithology, and tectonics of the coast (Gheith et al., 2005). Several researchers have published seminal studies of the southern Red Sea coast, including Alharbi et al. (2016), Alhazmi (2006) and Al-Washmi et al. (2005). Some of the most salient studies were carried out by Gheith and Abou Ouf (1996a) and Nabhan (2004), providing data on the geomorphological features, characteristics and distributions along the eastern Red Sea coastal plain. Further studies have taken the sedimentary characteristics as their focus and have considered the ways in which these
characteristics interact and affect the distribution of geomorphological features in the southern sector (Abou Ouf & El-Shater, 1992; Basyoni, 1997; Gheith, 2000; Khawfany, 2009; Tag, 1986).

The classification processes that affect the formation and growth of deposition environments have conducted by Al-Sayari and Zotl (1978), Arvidson et al. (1994), Bahafzullah et al. (1993), Davis (1985), Jado and Zötl (1984) and Manaa (2011).

The northern section of the Red Sea’s coastal plain is formed of a narrower bar than the southern coast. This observation suggests that continuous lifting operations have taken place along the northern coast, as opposed to the southern coast, which has been plunged into and covered by sediment at a faster pace (Coleman, 1993).

Many of the reliefs and the geomorphic terrains that have formed on the Red Sea’s coastal plain can be attributed to tectonic movements that occurred during the late Quaternary. Both the arid climate of the region and the erosional processes of the coastline have had an effect on the evolution of the alluvial plain, thereby contributing to the current scene and geomorphology (Coleman, 1993).

Beach development is structurally controlled by different sub-environments (Short & Masselink, 1999), such as lagoons, intertidal zones, sabkhas, wadis, and sand dunes. Behaviours of high complexity are sensing techniques in order to create geomorphological and sabkha maps of the Jeddah coast. Additionally, Qari and Basyoni (2003) demonstrated the vital role that the Landsat TM digital data plays in sabkha studies along the Red Sea coast and in similar areas. Alhazmi (2006) and Alharbi et al. (2011) investigated the morphodynamics of the coastline in Ash Shuqayq, a location on the southern Saudi Arabian coast. Furthermore, Nofal and Abboud (2016) used remotely sensed imagery data in order to identify a range of geomorphological and geological details in Ras Al-Shabaan, which is on the eastern Saudi Arabian coast. Landsat-8 data was also utilised by Khawfany et al. (2017) to produce multiple maps that illustrate a variety of natural land phenomena on the Jizan coast.

The aim of this paper is to identify the different geomorphological units characterised on the Rabigh coast through field investigations, combined with Sentinel 2 imagery data gathered afterwards. In this way, this study is considered to be a useful foundation for further geological research.

2. Physical Background

The northern coastal plain of the Red Sea is narrow: 1–40km wide. Behind the coastal plain is a major escarpment of 1500-3000m in height, which marks the uplift of the Arabian and African shield margins representing the structural edges of the region of the Red Sea Rift (Al-Sayari & Zotl, 1978). In the east, the Red Sea coastal plain and the shelf region are bound inland and seaward respectively owing to the shield escarpment and the sudden slope break signalling the Red Sea Trough edge (Brown, 1970).
engendered by several factors that are under continuous interaction in such sub-environments, including local geology, volume and texture of sediments, and external forces (e.g. action of waves or wind, fluctuations in climate) (O’Connor et al., 2007).

To the north of Al Wajh (Fig. 1a), the coastal plain measures less than 2km in width. It is an irregular, fault-controlled strip that comprises Miocene sediments and Quaternary alluvium and gravel. To the south, between Al Wajh and Jeddah (including Rabigh, shown in Fig. 1a and b), it widens and reaches an average width of 15km. Moving further south of Jeddah (Fig. 1b), it measures 40km at Jizan and widens further once it reaches as far south as Yemen (Skipwith, 1973). To the north of Al Lith, basement rocks interrupt the coastline 5km away from the ocean, between Ash Shuqayq and Hali (Fig. 1a). In the present context, a territory of plateau basalts expanding for more than 160km covers the surface area of the plain. The above-surface height of the 25-30 cylinder cones is 50-100m. Coral banks and reefal limestone with a coating of biogenous carbonate sand layer constitute the Red Sea marginal shelf in this area.

The most common type of reef is fringing reef, which is penetrated by narrow channels called sharms. Sharms are thought to have been formed by erosion in the pluvial Pleistocene and drowned by post-glacial sea level rise. A series of Late Pleistocene reefs exist that stand as wave cut terraces, rising between 1m and 12m above the modern sea,
along the coastal plain of the Red Sea (Sestini, 1965; Said, 1969). These terraces are enmeshed among raised beaches and dunes. Aside from these raised reef areas, the coast is low lying. It forms a supratidal sabkha; an environment protected by offshore bars, island chains, mangroves, or quiet water lagoons.

Moving inland from the coast, the plain rises at a gradient of 1:8. It moves into an eastern plain that is primarily composed of a piedmont with alluvium, outwash sands and gravel found on Tertiary or crystalline rocks. It continues in this manner up to the basement hills. There are multiple drowned estuaries (sharms) that slice through the coastal plain and extend towards the inner shelf. These reach depths of up to 50m below sea level. To the north of Jeddah, there are low hills of Tertiary strata outcropping from the coastal plain. Extending northwards, from Umm Lajj to the Gulf of Aqaba (Fig. 1a), there are multiple coralline rock raised surfaces that have been measured at 6m, 10m, 20m and 30m above sea level.

In the shore zone, the sediments are primarily composed of skeletal carbonate sands or gravel. In the nearshore zone, the sediments are primarily composed of coral fragments, coralline algae molluscs. The beach sediments are relatively finer than the nearshore sediments, with the exception of samples that are dominated by Cerithidea gastropods. Although sand-sized material occupies most of the beaches, fine lime mud and coarse clastic gravel can be found in some areas.

2.1. Description of the Study Area

The study area falls into the domain of the Makkah province (Fig. 1b and c) and is located on the eastern Red Sea coastal plain at latitudes 22° 45´ N and 23° N. Rabigh is circa 130km north of Jeddah City (Fig. 1b and c). The Al Kharrar lagoon lies north of Rabigh, and the Sharm Rabigh is situated in the southern area of the Al Kharrar lagoon (Fig. 1c). The area under consideration spans 23km of coastline, from the north of Sharm Rabigh to the beginning of the Al Kharrar lagoon.

Geologically, the coastal plain of the study area is covered by Quaternary deposits with an average width of approximately 30km. The deposits have been classified into several units, such as reefal limestone, which is the oldest unit along the coast. The presence of this limestone decreases towards the south, while the sabkha deposits are scattered around Sharm Al Kharrar and Sharm Rabigh, increasing towards the south. The alluvial terraces and fans, which are the most recent deposits that have been located at the east of the Rabigh coastal plain, are crossed by major wadies, while the alluvium deposits (sand and gravel) fill the bottoms of the wadies (Fig. 2).

3. Methodology and Field Investigation

3.1. Sentinel 2 Data and Digital Image Processing

The Rabigh coastal area was studied using Sentinel 2 data from 22 January, 2020 (Fig. 3). Sentinel 2 is an Earth observation satellite set into orbit by the European Space Agency (ESA) on 7 March, 2017 (Sentinel 2B). It is part of the Copernicus programme, set in motion in order to perform terrestrial observations to provide data for services, such as marine environmental monitoring and management, coastal zone mapping and the identification of landforms (Bergsma and Almar, 2020; European Commission, 2019; European Space Agency [ESA], 2015). The Sentinel 2 satellite sensor has 13 bands in the visible, near-infrared (VNIR) and short-wavelength infrared (SWIR) sections of the spectrum (Table 1) with a spatial resolution of 10m, 20m and 60m. Its satellite images are available on the USGS website (https://earthexplorer.usgs.gov/) (USGS, 2020).
This study’s methodology is devoted to the identification of coastal landforms. The workflow that was used is illustrated in Fig. 4. The data processing included a re-sampling of the Sentinel 2 bands at a resolution of 20m in order to produce a layer-stack of 10m spectral bands. Following this, pixel, object and index-based classifications were achieved. The procedures for digital image processing were completed using Erdas Imagine 2014 software (ERDAS Field Guide, 1999). Unsupervised and supervised classifications were conducted in order to separate the landforms from other land covers. In the unsupervised classification, the image (Sentinel 2 satellite) was classified into 20 different classes using the k-means method (Kaplan & Avdan, 2017; Piloyan & Konečný, 2017). The pixels were classified depending on their reflectance properties. The groups created from this classification were named ‘clusters’. Demonstrative samples of each landform class had to be selected in order for the supervised classification to take place. The classification was based on spectral signatures that were determined by the user. These techniques had value in varying geological and geomorphological applications, including landform units and coastal plain mapping and management (Abdel-Kader et al., 1998; Alharbi et al., 2011; Dewidar & Frihy, 2003; Mohamed, 2020; Nofal & Abboud, 2016; Samanta et al., 2012; Visalatchi & Padmanaban, 2012). The study allows identification of nine classes: deep water, shallow water (including lagoons), fringing reef, vegetation, sabkhas, sandy shores and tidal flats, alluvial terraces, alluvial deposits (including wadis) and reef terraces. The maximum likelihood (ML) parametric rule was used when carrying out classifications (Keuchel et al., 2003).

![Geologic map of the Rabigh Quadrangle (study area) in the Red Sea, Saudi Arabia (after Ramsay, 1986).](image-url)
Fig. 3. Sentinel 2 data from 22 January, 2020 used for studying the Rabigh coastal area.

Table 1. The 13 Sentinel 2B bands used in the present study (EOS, 2020).

<table>
<thead>
<tr>
<th>Band Number</th>
<th>Band Description</th>
<th>Wavelength (nm)</th>
<th>Resolution (m)</th>
</tr>
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<tbody>
<tr>
<td>B1</td>
<td>Coastal erosion-Ultra blue</td>
<td>442.3</td>
<td>60</td>
</tr>
<tr>
<td>B2</td>
<td>Blue</td>
<td>492.1</td>
<td>10</td>
</tr>
<tr>
<td>B3</td>
<td>Green</td>
<td>559</td>
<td>10</td>
</tr>
<tr>
<td>B4</td>
<td>Red</td>
<td>665</td>
<td>10</td>
</tr>
<tr>
<td>B5</td>
<td>Vegetation Red Edge-VNIR</td>
<td>703.8</td>
<td>20</td>
</tr>
<tr>
<td>B6</td>
<td>Vegetation Red Edge-VNIR</td>
<td>739.1</td>
<td>20</td>
</tr>
<tr>
<td>B7</td>
<td>Vegetation Red Edge-VNIR</td>
<td>779.7</td>
<td>20</td>
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<tr>
<td>B8</td>
<td>VNIR</td>
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<td>10</td>
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<tr>
<td>B8b</td>
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<td>20</td>
</tr>
<tr>
<td>B9</td>
<td>Water vapour</td>
<td>943.2</td>
<td>60</td>
</tr>
<tr>
<td>B10</td>
<td>SWIR – Cirrus</td>
<td>1376.9</td>
<td>60</td>
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<td>B11</td>
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<td>1610.4</td>
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<td>B12</td>
<td>SWIR</td>
<td>2185.7</td>
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</table>
3.2. Field Investigation

Multiple field visits were conducted to identify the different coastal geomorphic units in the study area in order to confirm the results obtained through the digital image processing. Once located, each feature’s location was recorded, studied and photographed. This study combined Sentinel 2 image processing with field data in order to improve accuracy in investigating and identifying multiple geomorphic features.

4. Results and Discussion

4.1. Landform Classification

The popularity of the approach of using satellite image data to digitally classify landforms stems from the fact that it is a quick process, and a high temporal resolution can be derived from the source data (Jensen & Christensen, 1986). According to the findings, the unsupervised classification yielded 20 distinct classes (Fig. 5), which made it difficult to distinguish between landforms. In contrast, the supervised classification was proven to perform better, delineating the fringing reef, sandy shore and tidal zones, reef limestone (including the reef terraces), sabkhas, wadis, vegetation (including land vegetation and mangroves), lagoons or sharms (including Sharm Rabigh and Sharm Al Kharrar lagoon) and sea water (including deep and shallow water). Table 2 shows how the landforms identified through supervised classification are spatially distributed.

Figure 6 illustrates the various land covers delineated through the supervised
classification. In this figure, deep and shallow water (lagoons) are coloured in dark and light blue, respectively; the fringing reef stretching along the Rabigh and Al Kharrar coast and isolated groups of reef islands are coloured in red; the sand shore and tidal zone are coloured in navy; the vegetation cover, including the mangroves, is coloured in green; the coastal plain, including the sabkhas, is coloured in orange; the reefal limestone and reef terraces are coloured in brown; the alluvial deposits and wadis are coloured in yellow; and the alluvial terraces are coloured in grey. The use of imaging from supervised classification helps in identifying the shoreline; the shoreline morphology is characterised by a number of features. Lagoons, reef terraces and tidal zones were found to be the dominant landforms along the winding coastline of the research area.

4.2. Coastal landforms Identified in Rabigh

The Rabigh coast is situated approximately 130km north of Jeddah. It is about 10km wide and is bordered to the east by Tertiary mountains. The area investigated in this study spans the coastline, starting in the north of Sharm Rabigh and ending at the start of the Al Kharrar lagoons. The beaches consist of narrow and poorly developed pocket beaches at irregular intervals. The shore is backed by coral reef terraces toward the land. The area is characterised by very productive biological ecosystems. The coast is considered narrow with a high relief depositional coastal plain covered by a consolidated coral reef platform that extends more than 10km toward the east. The research approach integrated digital image processing and field analysis that revealed a series of geomorphological features of particular surficial sediments that are briefly outlined below. The coast is emerged with hard coral reef limestone (raised reef terraces), ranging in height from 1–6m, and is covered by alluvial and aeolian gravelly sands. The beaches on Rabigh sometimes occur as pocket beaches; the raised beach rocks and coral reef terraces form the headland. The shore is a narrow sand beach. The beach rocks in the area are irregularly distributed. Seaward, the shoreline of the nearshore zone is an area of shallow water spreading nearly 150m wide, consisting almost entirely of a hard coral reef platform that is generally flat and is covered by a thin-layer of unconsolidated coarse-grained to fine-grained skeletal carbonate fragments and coral reef particles of the Holocene age (Gheith and Abou Ouf, 1996b), up to what is known as the Al-Kassara reefal bar. The nearshore zone is the dynamic zone dominated by breaking waves and wave-induced currents.

4.2.1. Fringing reef

The features that dominate the Rabigh coastline are the coral reefs, patch reefs and small reef islands that are dispersed at a distance from the shore and are often underwater. The reefs are concentrated in the north and south sections of the research area. In the Al Kharrar lagoon, the corals circumscribe the coast and islands, as can be seen in Fig. 6 and 7.

4.2.2. Sandy shores and tidal flats

Stretching from north to south, across a distance of over 30km, the shoreline in the research area generally has a winding characteristic. This is owing to the occurrence of features such as reef terraces and sandy shores, with borders of inter-tidal flats along the coast of Rabigh spanning a length of approximately 11km², which are indicated by the grey colour (Table 2; Fig. 6; Fig. 8a, b, and c). Calcareous sediments are the origin of the sandy and muddy characteristics of the Rabigh shore that, in turn, are likely to have been derived from the erosion of reef limestone terraces along the coast and from the hard reefal bars common in the nearshore zone. The shallow nearshore zone surface is relatively
smooth in profile sloping gently seaward till the edge of the reef flat (Al Kassara).

4.2.3. Salt marshes and sabkhas

Among the predominant geomorphological features along the Rabigh coastline are sabkhas that occur in uneven clusters in the northern part of the study area and in broader expanses in the southern and eastern parts of the Al Kharrar lagoon, penetrating approximately 2km inland and spanning an area of circa 55km² (Table 2; Fig. 6). As indicated by the yellow colour in Fig. 6, a raised sandy berm made up of alluvial deposits is located between the sabkhas and the lagoons in certain areas, especially in the northeastern section, with shallow water sometimes submerging sites that are at a low elevation. Furthermore, factors such as seasonal fluctuations in the level of the water table, tidal patterns, the amount of precipitation and the evaporation rate determine whether the sabkhas along the Rabigh coastline are wet or dry (Fig. 9a and b). Silt and fine sand that vary in colour from light to dark brown dominate the composition of the sabkha sediments, while salt crust (halite) covers some of these sediments (Fig. 9c), depending on the moisture and/or content of organic matter.

4.2.4 Vegetation

There are two types of vegetation in the research area – plants commonly encountered in urban zones (Fig. 6) and halophytes occurring on sabkhas, marshes and sand dunes with extensive distribution along the coastal plain in the research area (Fig. 10a). However, the vegetation cover is not equally dense in all sites, which is indicated in the supervised classification images by the green colour (Fig. 6).

The Rabigh coastline is not rich in mangroves (Fig. 10b and c). Stands of Avicennia marina mangroves are predominant only around the Al Kharrar lagoon (Fig. 6). During the rainy season, this lagoon sporadically receives fresh water from the flash flooding of numerous wadis that are present in its south to southeast areas (Fig. 6).

4.2.5. Sand dunes

Small sand dunes traced are found along the northern coast in the research area, reaching heights of 0.30–0.50cm and widths of 1–10m. They consist of uninterrupted clusters of fine-to-medium sand, unified by vegetation (nabkas) that are specially adapted to sand dunes (Gómez et al., 2002) (Fig. 11a). These adaptations include resistance to substrate movements exposing and covering their roots, resistance to desiccation, resistance to winds of high strength transporting salt and sand, as well as resistance to extreme temperature fluctuations (Esler, 1970), as can be seen in Fig. 11b. In addition, sand sheets are also noticed, comprising uniform, large-size or thin-laminated silt and fine sand grains of high porosity, alongside dispersed vegetation and rootlets.

4.2.6. The Wadis

The supervised classification images revealed three wadi basins that are highlighted in Fig. 6 in yellow colour, alongside the alluvial deposits. Running along the eastern side of the mountain piedmont in the direction of the coast, the wadis create a geomorphological feature resembling a fan with supplied material from the alluvial terraces shown in Fig. 6 in a grey colour. The formation of wadis occurs during intervals of high levels of precipitation and flash flooding, with a high level of activity in the sporadic stream drainage, as large quantities of sediments are delivered to the mouths of the wadis and to the coast. The estuaries of several wadis, including wadi Muraykh, wadi Al Hablis and wadi Rabigh, are responsible for the terrigenous deposits that have been noted along the eastern part of the Al Kharrar lagoon (Fig. 1 and 6). Sand sheets, sabkhas and vegetation are the dominant features of these estuaries. Sand sheets take the form of a homogeneous, flat
surface consisting of sand-sized sediments, while sabkhas are found along the eastern part of the Al Kharrar lagoon at the mouth of the estuaries (Fig. 2 & 6). Meanwhile, mangroves occur in the southern part of the Al Kharrar lagoon, in the estuary formed by the confluence of the Rabigh and Al Hablis wadis.

4.2.7. Raised coral reef terraces

Depicted in a brown colour in Fig. 6, emergent reef limestone taking the form of raised reef terraces that are the dominant geomorphological features along the Rabigh coast, with heights up to 6m above the average sea level. As shown in Fig. 12a and 12b, a superior and inferior reef were distinguished. These are characterised by nearly complete flatness, with a slight slope inland, and covered by mixed calcareous alluvial deposit (shown in Fig. 6 by the yellow colour) originating from the nearly high-fringed mountains on the eastern side of the Al Kharrar lagoon, which are primarily made up of crystalline rocks.

4.2.8. Beach rock

Beach rocks are found alongside the raised reef terraces close to the coast, and they are approximately 20–30cm thick (Fig. 13a and b). They take the form of a raised, wide and inclined bar in two terraces with a displacement of 0.5m. There are also beach rock slabs dispersed randomly on the beach. On the whole, the distribution of beach rocks within the research area is irregular and scattered. In terms of texture, the beach rocks do not differ very much from the beach skeletal carbonate sediments on the adjacent foreshore. This is because these rocks originate from beach sediments that have been subjected to marine cementation processes. Furthermore, the beach rocks exhibit graded lamination with a fining upward sequence, and well-sorted coarse and fine grains occur alternately. Occasionally, algal films coat the surface of consolidated beach rocks. Beach rocks are frequently encountered on shores in tropical and subtropical areas. Beach rocks develop in certain climatic and physiographic conditions where calcium carbonate cements precipitated from sea water and/or groundwater, as the binding material (Moore, 1973). However, Basaham (2004) found that the aragonite and high magnesium calcite cement in Rabigh beach rocks proved that precipitation takes place from sea water.

4.2.9. Lagoons

The Sharm Al Kharrar and Sharm Rabigh lagoons are found to the northwest and south of Rabigh, respectively (Fig. 1c & 6). The formation of the lagoon basins occurred during the fracture of the reef limestone under tropical and subtropical conditions. The Rabigh coast is bordered by hills and mountains made of granitic and metamorphic rocks, reaching heights of over 700m. A narrow channel links the Sharm Al Kharrar lagoon to the Red Sea on its north-western side. This lagoon is subject to the influence of longshore currents with high levels of aragonite and magnesium calcite as shallow water carbonates (Al-Washmi, 1999). The composition of both lagoons is dominated by clastic sediments from ancient valleys, resulting in limited diversity and coverage of corals similar to the inferior reef (Manaa, 2011).
Geomorphologic Features Characteristic of the Rabigh Coastal Area of the Eastern Red Sea, Saudi Arabia ...
Fig. 6. A supervised classification image showing nine major classes of geomorphological and geological features in the study area.

Fig. 7. Coral reefs along the Rabigh coastline.
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Fig. 8. Shoreline geomorphic features: (a) Reef terrace; (b) Sand shore; (c) Tidal flat.

Fig. 9. Sabkhas along the Rabigh coastline: (a) Wet sabkha; (b) Dry sabkha; (c) Sabkha surface covered by white halite.
Fig. 10. Vegetation habitats: (a) Sand dune vegetation; (b) and (c) The limited distribution of mangroves in the research area.

Fig. 11. Sand dunes landform: (a) Sand dunes and nabkas with vegetation cover in the northern section of the research area; (b) Sand sheet with cover consisting of dispersed vegetation in the same section of the research area.
4. Conclusion

Land features can be effectively examined by employing remote sensing technology to process and analyse satellite images. With the aim of differentiating geomorphological features close to Rabigh, this study used Sentinel 2 data to do both supervised and unsupervised classification. This strategy was integrated with field observations. Among the features discerned in this way were coral reef terraces, beach rocks, salt marshes and sabkhas, lagoons, fringing reef, sandy shores and tidal flats, wadis, deep and shallow water. The variants of supervised classification were helpful in identifying deep and shallow water,
the coastal zones of sabkhas, vegetation distribution, reefal limestone constituting reef terraces and beach rocks, as well as the coastline between the water and the land. The present results can be used by the Rabigh authorities to guide regional development. This is particularly important as this city is an industrial centre and located close to key economic and development hubs in Saudi Arabia, such as King Abdullah Economic City and King Abdullah Port.

Declaration of Competing Interest

The author declares that there are no potential conflicts of interest.

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References


السمات الجيومورفولوجية لمنطقة رابغ الساحلية في شرق البحر الأحمر، المملكة العربية السعودية، باستخدام الدراسات الميدانية وصور القمر الصناعي "سنتينيل 2": عمر على العربي
قسم الجغرافيا، كلية العلوم الاجتماعية، جامعة أم القرى، مكة المكرمة، المملكة العربية السعودية
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المستخلص. تقوم الدراسة بوصف الأشكال الأرضية الساحلية على طول المنطقة الساحلية لرابغ على الجانب الشرقي من السهل الساحلي السعودي للبحر الأحمر، وكذلك العمليات المؤثرة على الجيومورفولوجية الموجودة على الساحل. وتتنوع التضاريس التي تحدث في المناطق الساحلية، وتشمل الشواطئ الرملية، ومناطق المد والجزر، والكثير من السبخات (المسطحات الملحية) والمستنقعات، ومصاطب الشعاب المرجانية المرتفعة، وصحور الشاطئ، والبحيرات، والشعاب المرجانية، والمواد الأرضية، والرواسب الغريبة. وتشير هذه التضاريس إلى أن الظروف على هذه الشواطئ قد شهدت تغيرًا سريعاً. وتتميز الأغطية الطبيعية المختلفة بإختلاف أنواع القمر الصناعي "سنتينيل 2" لتقنيات معالجة الصور الرقمية. كما تم التحقق من صحة النتائج التي تم الحصول عليها من خلال العمل الميداني. كان التصنيف الموجه فعالًا بشكل خاص في التمييز بين الشعاب المرجانية، ذات اللون الأحمر، ومن الحجر الجيري للشعاب وهو بيئي اللون. علاوة على ذلك، أشار التصنيف الموجه إلى أنظمة تصنيف الأزهار والمصابيح في عدد من المناطق، وتحديداً في الجزء الجنوبي من خور الخراب، حيث يتم تصنيف أودية رابغ. وتكشف الصور التي تم معالجتها بوضوح كيف يتم توزيع الأشكال الأرضية المختلفة. وتعتبر النتائج التي تم التوصل إليها ذات قيمة أساسية، ليس فقط للأبحاث الجيولوجية والهندسية والبيئولوجية المستقبلية، ولكن أيضًا لصناع القرار.

كلمات مفتاحية: مصاطب الشعاب المرجانية، بيانات سنتينيل 2، التصنيف الموجه، السمات الجيومورفولوجية، المملكة العربية السعودية.