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## Delineating and Calculating the Length of Yemen's Mainland Shoreline

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**Abstract:**

The Republic of Yemen is one of the countries gifted with a long coastal line. The coastal zone is rich with biodiversity and a wide range of coastal ecosystems, which is vital to the livelihood of the coastal communities. Despite the fact that several studies have described its coastal characteristics, there are still obvious variations in stating the actual length of its shoreline. In many reports and research studies, the coastline length of Yemen's mainland has been reported with different figures such as 1,906, 2,000, 2,100, 2,200, 2,300, 2,350, and 2,520 km. This research paper aims to substantiate the actual shoreline length of Yemen, in addition, to calculate the length of each coastal governorate and district using GIS tools. This study showed that the total length of Yemen's mainland shoreline is about 2,252 km, with approximately 770 km overlooks the Red Sea and 1,482 km of the southern shoreline that overlooks the Gulf of Aden and the Arabian Sea. Among the coastal governorates of Yemen, Al-Hodeidah Governorate has been found to have the longest shoreline of about 519.7 km, whereas Hajjah Governorate has the shortest shoreline of about 92.7 km. As for coastal districts, Rudum District (Shabwah Governorate) has been found to have the longest shoreline of about 190.5 km. This research paper could provide some baseline information for other research works related to the coastal area of Yemen.



## INTRODUCTION

The shoreline is the boundary between both terrestrial and ocean environments. It is a dynamic area which is influenced by different geological and climatic processes that make the shoreline in a persistent changing, and its features are temporary. Most of the world's countries are interested in their shorelines, as a part of the coastal zone. About 40% of the world's population occupies the area within 100 km of the coastline (Noronha, 2003). This area is vulnerable to natural and human processes and during the past decades, it strongly subjected to fast-growing urban development (Sonak *et al.*, 2000). On the other hand, this area is biologically very productive (Noronha, 2003), and is considered an important food source as many species favor living in this zone. Many coastal environments are located in the coastline such as sandy, muddy, and rocky shores, in addition to mangrove ecosystems which are considered the most sensitive marine habitats that host a vast variety of marine organisms (Jagtap and Nagle, 2007).

Yemen is one of the countries which have a long coastal line. It is located in the southwest corner of the Arabian Peninsula, with a coastline on the Red Sea, the Gulf of Aden, and the Arabian Sea. The coastal zone is rich with biodiversity and a wide range of coastal ecosystems, which is vital to the livelihood of the coastal population (Abubakr, 2004).

Several studies have been conducted on the coastal zone of Yemen and described its geographic, geological, social, and ecological characteristics. However, there are still obvious variations in stating the actual length of its coastline. Most of the reports and research studies stated that the length of coastline is 2,200 km (PERSGA, 2001; HRI, 2001; PERSGA, 2003; FAO, 2005; Nagi and Abubakr, 2013), whereas it has been reported as 2,500 km in other documents (Shaher, 2007; EPA 2009; YRSGISC, 2010). On the other hand, EPA (2004), HoodOil (2004), and Brook *et al.* (2006) reported that the coastal line of Yemen is estimated to be 1,906 km. Moreover, Al Hababi (2006), Al Khirbash *et al.* (2019), EPA (2013),

Boufiglioli and Hariri (2004), and Al Absi and Teruhisa (2014) reported that the length of the Yemeni coastline is 2,000, 2,100, 2,300, 2,350, and 2,520 km, respectively.

The length of Yemen's western and southern coastline also showed a great variation among the previous reports and studies. For instance, concerning the western coast on the Red Sea, its length was reported by Krupp *et al.* (2007) and Benzoni *et al.* (2012) to be 760 km, whereas DouAbul and Haddad (1999) stated that it is 730 km. On the other hand, FAO (2005) and Shaher (2007) reported that Yemen's Red Sea coastal length is 650 km, while Al Hubaishi (1992) reported that its length is only 450 km. With regards to the southern coast of Yemen, on the Gulf of Aden and the Arabian Sea, its length is stated by FAO (2005) and Shaher (2007) to be 1,550 km, whereas Al Saafani *et al.* (2015) reported that it is 1,400 km. Moreover, Benzoni *et al.* (2012) mentioned that the southern coastline length is about 1,200 km, whereas Al Hubaishi (1992) stated that it is only 1,100 km.

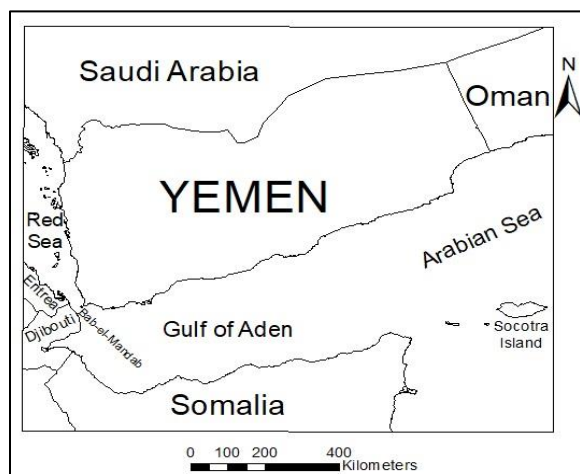
With respect to the coastline length of coastal governorates, Aldwila *et al.* (2018), and Hariri *et al.* (2009) reported the coastline length of Hadhramout and Al-Mahara Governorates to be 750 km and 550 km, respectively. According to this, both governorates should cover about 80 % of the total southern coastline. This is not possible if one takes a first glance at the southern coast map of Yemen.

With all the above contradictory information of Yemen's coastline length, the present research paper is aimed to describe the shoreline of Yemen's mainland and substantiate its specific length. The study will also estimate the shoreline length of each coastal governorate and district of Yemen.

## MATERIALS AND METHODS

In this study, the coastal line of Yemen is described from the northern border of Yemen with Saudi Arabia to the southern tip of the Red Sea at Bab-el-Mandab, and from the western side of the Yemeni coast on the Gulf of Aden

towards the eastern border of Yemen with Sultanate of Oman (Figure 1).



**Fig. 1.** Location of the Republic of Yemen.

Topographic maps of the coastal area of the former Yemen Arab Republic on 1:50,000 and 100,000 scale for the years 1985 - 1987, and the former People's Democratic Republic of Yemen on 1:100,000 scale for the years 1978 - 1982 were collected and scanned (Both countries were unified in the year 1990 to form the Republic of Yemen).

The scanned toposheets were geo-coded and converted to image format, which is then mosaiced together and used for tracing the shoreline using GIS techniques. The length of the shoreline for each coastal district and governorate of Yemen were estimated and the results were expressed in kilometers. The map of Yemen's districts was prepared by the Yemen Center for Remote Sensing and GIS (YRSGISC).

## RESULTS

The shoreline of Yemen starts from the border with Saudi Arabia at Ras Al-Muag, opposite the northern tip of Al-Doaimah Island in Hajjah

Governorate. Out of 31 districts in Hajjah Governorate, the coastal line passes through only two districts, which are Midi, with a shoreline length of about 82.6km, and Abs that has a shoreline that extends for about 10.1 km. The shoreline of Hajjah is characterized by its meandering features which expand its length to approximately 92.7 km.

South of Abs district, Al-Hodeidah Governorate is located. It has 11 coastal districts, viz. Al-Luhayya, Al-Muneera, Al-Saleef, Bajil, Al-Hali, Al-Mina, Al-Hawak, Al-Durayhimi, Bayt Al-Faqih, At-Tuhayta, and Al-Khawkhah. Those districts have a shoreline length of about 75.5, 34.6, 96.3, 41.4, 7.47, 66.6, 8.1, 87.8, 13.9, 58.8, and 29.2 km, respectively (Table 1). The coastal line begins to divert towards the southwest direction until Al-Luhayyah peninsula and *Ras Addwe'e*, then back again to turn slightly towards the southeast direction until the southern border of the governorate. The shoreline of Al-Hodeidah Governorate is characterized by its frequent meandering features. Several peninsulas, bays, and coastal spits have expanded the shoreline of Al-Hodeidah Governorate to reach a total length of approximately 519.7 km, which is double the straight line distance of the opposite Red Sea waters (about 262 km).

Taiz Governorate is the third coastal governorate that is located on the western coast of Yemen. Only two of Taiz's total 23 districts are coastal, which are Al-Makha (Mocha) and Dhubab with a shoreline length of about 69.6 and 97.2 km, respectively. The coastal line of this governorate extends slightly towards the southwest direction until the border of Al-Makha with Dhubab District. Afterward, it returns towards the southeastern direction until reaching Bab-el-Mandab peninsula, opposite of Mayyun (Perim) Island, at the strait of Bab-el-Mandab. Taiz Governorate has a shoreline of approximately 166.8 km in length.

**Table 1.** Shoreline Length of the Republic of Yemen's Mainland.

No	Governorate	District	Shoreline Length (km)	
1	Hajjah Governorate	Midi	82.6	92.7
		Abs	10.1	
2	Al-Hodeidah Governorate	Al-Luhayyah	75.5	519.7
		Al-Muneera	34.6	
		Al-Saleef	96.3	
		Bajil	41.4	
		Al-Hali	7.5	
		Al-Mina	66.6	
		Al-Hawak	8.1	
		Ad-Durayhimi	87.8	
		Bayt Al-Faqih	13.9	
		At-Tuhaytah	58.8	
		Al-Khawkhah	29.2	
3	Taiz Governorate	Al-Makha	69.6	166.8
		Dhubab	97.2	
4	Lahj Governorate	Al-Madaribah wa Al-Arah	133.1	133.1
5	Aden Governorate	Al-Buraiqah	127.7	206.7
		Al-Mansoorah	17.3	
		Al-Mu'alla	6.7	
		At-Tawahi	15.7	
		Crater	11.2	
		Khormakser	28.1	
6	Abyan Governorate	Khanfar	148.3	259.6
		Zinjibar	20.9	
		Ahwar	90.4	
7	Shabwah Governorate	Rudum	190.5	190.5
8	Hadhramout Governorate	Brom wa Mayfa	77.1	303.9
		Mukalla	58.9	
		Ghayl Ba-Wazir	7.1	
		Ash-Shihr	45.6	
		Ad-Dis	51.0	
		Ar-Raydah wa Qusayar	64.2	
9	Al-Mahara Governorate	Al-Masilah	43.0	379.5
		Sayhut	64.4	
		Qishn	34.0	
		Huswain	47.1	
		Al-Ghaydah	137.6	
		Hawf	53.4	
Total Length				2,252.5

As the southern side of the Bab-el-Mandab peninsula overlooks the Gulf of Aden waters, the remaining coastal line (~9 km) of Taiz Governorate, after *Ras Bab-el-Mandab* until the border of Lahj Governorate, could be considered the beginning of the Yemeni coastal line that overlooks the Gulf of Aden waters.

Despite the fact that Lahj Governorate contains a total of 15 districts, only one district (that is Al-Madaribah wa Al-Arah) is coastal. The shoreline

of Lahj Governorate extends eastwards with some winding features such as *Ras Al-Arah* and *Khor Al-Omera* Spits. Those features increase the coastal line of Lahj Governorate to a length of approximately 133.1 km (Table 2).

Aden Governorate coastal line starts from before *Ras Qa'wa* and extends to the northeast and then curves towards the southeast to make a crescent arc till *Ras Imran*. Then, the coastal line repeated the same and forms another crescent

arc until *Ras Foqam* in the western side of Little Aden peninsula, and then the peninsula of Aden (Crater, At-Tawahi, and Al-Mu'alla). These two peninsulas are characterized by their meandering coastal line which contributed to increase the length of the Aden Governorate shoreline. Following *Ras Ma'asheek*, the shoreline binds in a right angle towards the northern direction until the border with Abyan Governorate. The coastline passes through six out of Aden's total eight districts; these are Al-Buraiah (127.7 km), Al-Mansoorah (17.3 km), Al-Mu'alla (6.7 km), At-Tawahi (15.7 km), Crater (11.2 km), and Khormakser (28.1 km). The shoreline of Aden Governorate is calculated to reach a total length of about 206.7 km (Table 2).

Once the shoreline enters Abyan Governorate, it binds towards the eastern direction making a coastal arc that ends at the opening of *Wadi Bana*. It then diverts to the northeast direction and heading back again to the east till the border of Shabwah Governorate. Out of the eleven districts, only three coastal districts at Abyan Governorate, which are Khanfar, Zinjibar, and Ahwar with a coastal length of about 20.9, 148.3, and 90.4 km, respectively. The total length of Abyan's shoreline is calculated to be approximately 259.6 km (Table 2).

In Shabwah Governorate, the coastline continues straightened towards the northeast direction till it bends with an arc towards the southeast until it reaches *Ras Al-Nasheemah* at Belhaf. Afterward, the coastline binds towards the eastern direction until Hadhramout Governorate border with several meandering characteristics. The shoreline of Rudum district, which is the only coastal district of Shabwah Governorate (total 17 districts), extends for about 190.5 km (Table 2).

The shoreline of Hadhramout Governorate extends for approximately 303.9 km. It is characterized by its northeastern direction with a mixture of straight long coasts intervened with several wave-cut platforms such as *Ras Rajemah*, *Ras Dhaloma*, *Ras Broom*, *Ras Khalf*, *Ras Sharma*, *Ras Baghashwa*, *Ras Rayqoob*, etc. Out of the 30 districts that Hadhramout

Governorate is consists of, there are only six coastal districts. These are Brom wa Mayfa, Al-Mukalla, Ghayl Ba-Wazir, Ash-Shihr, Ad-Dis, Ar-Raydah wa Qusayar, with a coastal line length of about: 77.1, 58.9, 7.0, 45.6, 51.0, and 64.2 km, respectively (Table 2).

The coastline of Al-Mahara Governorate is similar to that of Hadhramout. It has long straight shores with numerous wave-cut platforms such as *Ras Sharwa*, *Ras Dargah*, *Ras Fartak*, *Ras Nashtoon*, *Ras Dharbat Ali*, etc. The shoreline continues in the northeastern direction until *Ras Fartak*, then it turns in a right angle to the north till *Thubut* village and then curves towards the northeastern direction again until the border of Yemen with the Sultanate of Oman at *Ras Dharbat Ali*. There are six coastal districts out of nine in Al-Mahara Governorate, viz. Al-Masilah, Sayhut, Qishn, Huswain, Al-Ghaydah, and Hawf, with a shoreline length of about 43.0, 64.4, 34.0, 47.1, 137.6, and 53.4 km, respectively. The total length of Al-Mahara shoreline is approximately 379.4 km (Table 2).

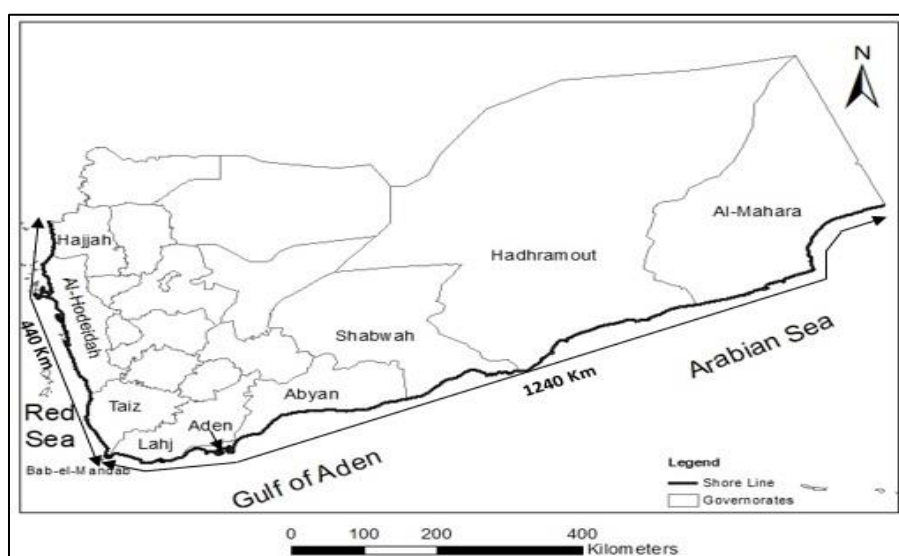
The location of each coastal governorate is illustrated in Figure 2, whereas the length of shoreline in every coastal district and governorate of the Republic of Yemen is shown in Table 2.

## DISCUSSION

The Yemeni coastal line extends from the border with northern Saudi Arabia on the Red Sea waters and heading south towards Bab-el-Mandab, and then turns towards eastern direction on the Gulf of Aden and Arabian Sea until the border with Sultanate of Oman. It is characterized by a variety of marine and coastal habitats including Sabkhas, saltmarshes, subtidal soft bottoms, sandy, muddy and rocky shores, mangroves, seagrasses, coral reefs, in addition to rocky headlands with series of cusped beaches in-between (Sheppard *et al.*, 1992; DouAbul, and Haddad, 1999; EPA, 2009; Nagi *et al.*, 2012; Hariri and Nagi, 2013; Al Saafani *et al.*, 2015).

**Table 2.** Expansion Percentage of Shoreline due to Coastal Features.

Sr. No.	Governorate	Shoreline Length (km)	Approx. Straight Length of the Front Coastal Waters (km)	Percentage of Expansion
1	Hajjah Governorate	92.7	58.9	57.5%
2	Al-Hodeidah Governorate	519.7	262.2	98.2%
3	Taiz Governorate	166.8	126.7	31.7%
4	Lahj Governorate	133.1	107.1	24.3%
5	Aden Governorate	206.7	96.7	113.8%
6	Abyan Governorate	259.6	244.1	6.4%
7	Shabwah Governorate	190.5	170.8	11.6%
8	Hadhrumout Governorate	303.9	272.7	11.4%
9	Al-Mahara Governorate	379.5	340.0	11.6%
<b>Total Length</b>		2,252.5	1,679.2	34.1%

**Fig. 2.** The Shoreline and Coastal Governorates of Yemen.

The coastal line of Yemen is described by its richness of marine ecosystem and its high biological diversity (Abubakr, 2004).

When tracing the shoreline of Yemen's mainland, it is obvious that the coastline is characterized by its meandering features in the western coastal governorates. On the other hand, the southern governorates are characterized by their straight lines with several scattered meandering features. This could be attributed to the wave action that prevailed in the area. Therefore, when a straight line is drawn in the Red Sea waters opposite Yemen's shoreline, the total length of this line is about 440 km. The total length of the western shoreline is calculated

to be approximately 770 km, from the border of Yemen with Saudi Arabia till *Ras Bab-el-Mandeb* opposite of Mayyun (Perim) Island at the strait of Bab-el-Mandab. The total length of the southern shoreline is calculated to be about 1,482 km which overlooks approximately 1,240 km (Straight line) of the Gulf of Aden and Arabian Sea waters till the eastern border with the Sultanate of Oman. Those meandering features have extended the western coast by about 72%, whereas the rare meandering features with the long straightened shores in the southern coasts increased its length by only 22% approximately. This expansion would create an opportunity to increase the number of organisms that inhabit

the intertidal zone, and accordingly increases the coastal biodiversity of Yemen.

The Republic of Yemen consists of 22 governorates, out of which, 21 are located on the mainland and only one governorate (Socotra) is an island located in the Arabian Sea. Out of the 21 mainland governorates, only 9 governorates are coastal; three overlooks the western Red Sea waters (Hajjah, Al-Hodeidah, and Taiz), and 6 overlooks the southern Gulf of Aden and Arabian Sea waters (Lahj, Aden, Abyan, Shabwah, Hadhramout, and Al-Mahara).

Al-Mahara and Hadhramout Governorates might appear to have the longest shoreline, as both governorates confront the longest Yemeni coastal waters (340 and 272.3 km, respectively). However, it was found that the longest shoreline among Yemeni governorates is the Al-Hodeidah Governorate with a length of approximately 519.7 km, which overlooks about 262.2 km only of the Yemeni coastal waters. The Meandering features in Al-Hodeidah Governorate such as the several peninsulas (Al-Saleef, Al-Katheeb, and Ras Al-Sha'b), bays, and creeks have expanded the shoreline by about 98%. Those features also appear in Aden Governorate as the large two peninsulas of Little Aden and Aden, in addition to other meandering features, increased the shoreline by about 114%.

With respect to the governments' districts, Yemen consists of a total of 331 districts in the mainland (YRSGISC, 2010). Out of which, only 38 are coastal districts that are distributed in the above 9 mentioned governorates. Fifteen districts are located in the western coastal governorates, whereas 23 are located in the southern governorates. During the present study, Rudum District in Shabwah Governorate has been found to has the longest shoreline of about 190.5 km, whereas Al-Mu'alla District in Aden Governorate was found to has the shortest shoreline (6.7 km) among all Yemeni districts.

The total length of Yemen's shoreline is calculated during this study to be 2,252.5 km. This result substantiated the length that was mentioned in PERSGA (2001), HRI (2001), PERSGA (2003), FAO (2005), Nagi and

Abubakr (2013). It is recommended that additional study should be conducted to estimate the shoreline length of Yemeni islands in order to calculate the total length of Yemen's shoreline, either of the mainland or its islands.

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## CONFLICT OF INTEREST

The authors declare that this article's content has no conflict of interest.

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