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The Role of Topography in Reducing the Impact of Global Sea Level Rise; a Case Study on the Northwestern Coast of Libya

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الملخص

يعد ارتفاع مستوى سطح البحر مشكلة حقيقية للحياة على سطح الكرة الأرضية ، حيث يؤدي هذا الارتفاع إلى غمر عدد كبير من المدن البحرية بالمياه. لذلك ، سيتم إجراء الدراسة الحالية في الساحل الشمالي الغربي لليبيا لتحديد تأثير ارتفاع مستوى سطح البحر في المستقبل عن طريق رسم خرائط مناطق الفيضانات باستخدام نظام المعلومات الجغرافية (GIS) من خلال تنفيذ طريقة قاعدة ثمانية جوانب كخوارزميات في سيناريو متر واحد ارتفاع مستوى سطح البحر ، هذه الدراسة تعتد اساسا على البيانات الطبوغرافية التي يتم تمثيلها في نماذج الارتفاع الرقمية، والتي يتم استخدامها كبيانات إدخال للتحليل المكاني والمنتجات المشتقة وتحديد المنطقة المعرضة للفيضانات والمخاطرالتي تنجم عنه. وعليه, تم تحديد مساحة الفيضانات 532.62 كيلومتر مربع بنسبة 16.73٪ من إجمالي المساحة ، ويشمل هذا التأثير المناطق الحضرية والزراعية والطرق ورمال الشاطئ والسبخات والأراضي القاحلة. علاوة على ذلك، تتركز هذه التأثيرات في الجزء الغربي من منطقة الدراسة. علاوة على ذلك ، فإن السكان ليسوا معزولين عن الخطر الذي سيشكل تهديدًا لحياتهم حتى لو حاولوا التكيف ما لم يتم تهجيرهم إلى مناطق أكثر أمانًا تتجلى في الجزء الشرقي من منطقة والتي تعتبر مقيدة ومدعومة بالطوبوغرافيا وهي مثالية لتجاوز مستوى المخاطر ، وكذلك بناء الحواجز الخرسانية ، والحد من الهجرة ، والتحكم في اتجاهات النمو السكاني .

Abstract

Sea level rise (SLR) is a real problem for life on the surface of the globe, as this rise leads to the inundation of a large number of marine cities in water. Therefore, the present study will be conducted in the northwest coast of Libya to determine the impact of future SLR through flood zonation mapping using the Geographical Information System (GIS) by implementing method of an eight-side rule as algorithms at scenario of one meter SLR, depending mainly on topographic data that represented in digital elevation models DEMs (SRTM), which be utilized as an input data for spatial analysis and derivative products and identify the area flooding and determine the vulnerable and risky area. The flooded area is indicated 532.62 km2 with 16.73% of the total area, this effect includes urban, agricultural, roads, beach sand, sabkhas, and barren lands. Moreover, these effects are concentrated in the western part of study area. Furthermore, the residents are not isolated from the danger that will pose a threat to their lives even if they try to adapt unless they are displaced to safer areas that are evident in the eastern part, which is restricted and supported by topography is ideal for exceeding the level of risk, constructing concrete barriers, limiting migration, and controlling population growth trends.

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Keywords*: sea level rise, flood hazard, digital elevation models, geographical information system*

1. Introduction

The To begin with, climate variation is a widely known happening associated with a lot of environmental and physical consequences. World climate has experienced a lot of changes in diverse ways throughout differing geological aeons. Such reported alterations did not happen abruptly; rather, they took place successively over centuries. However, the current observed changes in climate exhibit a rather different tempo. Departing significantly from the historical patterns, these changes seem to exhibit more brutal and rapid behaviour, suggesting that this CC is not brought about by factors related to the Mother Nature. Rather, this change has a lot to do with what is referred to as the global cycle of carbon. This cycle refers to a natural process where carbon exchanges take place among the atmosphere, the lithosphere, as well as the biosphere. In the course of the past century or so, the whole anthropogony-induced discharge arising from nonrenewable sources and large-scale manufacturing businesses (e.g., manufacturing of concrete or cement), let alone changes brought about by land use, appeared to have played havoc with the nature-bound balance present in distinct composites of the world-wide cycle of carbon in the earth's ecosystems [1]. Apparently, an enormous build-up of gaseous compounds often referred to as greenhouse gases (GHGs) and aerosol substances in the atmosphere have been brought about by human diverse actions throughout the past and present centuries [2], regulating partly the climate on the earth in such a way that the short-wave energy emitted from the sun passes through the molecules and the gases in the atmosphere, and hence entraps the longer wave radiation reflected from Earth [3].This increases the density of aerosol substances as well as that of GHGs to a large extent. Other mishaps that added to the pre-existing problems and have led to big changes in forest lands world-wide and agrarian expansions, never mind urbanization issues. The point is, substantial changes related to energy equilibrium are brought about by considerable disturbance and lessening of natural sequestration activities of carbon dioxide governed by processes of plant photosynthesis. By the same token, the ozone layer exhaustion adds to the severity of the situation owing to the expansion in the radiative flux density of the sun. On this account, the categorical rise in world temperature can be unravelled [4]. Details this earth warming-induced expansion from 1880 to 2015 explained by (Dagbegnon, Djebou, & Singh, 2016; IPCC (2014)) Jepma, Munasinghe, Bolin, Watson, and Bruce (1998) that was because of a rapid accumulation of greenhouse gases in the atmosphere as a result of the use of energy since the beginning of the industrial revolution, which is topped by carbon dioxide(CO2), methane(CH4), and nitrous oxide(N2O), where records of levels higher than the normal or historical. It has been predicted that in the year 2100 the global climate needs the use of wide models. The modelling is assumed three different levels of sensitivity of the global climate (Global temperature) to (high 4.5, medium 2.5 and low 1.5). This increase in the global temperature does not capture considerable regional and local temperature variations in this impact. Moreover, a slight increase in the average is probably to induce large increase in extreme climate events. For instance, the maximum temperature in hot days exceeds 40c. All of these factors are combined to cause heat expansion of the oceans as well as ice sheets and glaciers melting [5]. Additionally, by the second half of the next century 40% of the people around the world will face actual serious shortage in the drinking fresh water due to melting of glacier [6].

Large population live in the coastal areas, in the 1990s 21% and 37% of the world's population were estimated to live within 30 km and 100 km, respectively, of the coastline. As well as, the population density of the coastal zones (CZs) is reached to three times the average of the world's population, and by 2030 it is expected that about 50% of the world population will live within 100 km of the CZs. A large proportion of the world's economic productivity is obtained from coastal areas due to the concentration of human settlements as well as the containment of many large cities near their coastline or directly on their shores. Trends towards urbanization are probably increasing the population densities in Lowlands CZs; it is estimated that the people who live within 30 Km of the coastal zones are increasing at twice the global mean, As a result of global economic well-being that coastal areas are blessed with, it became a major reason for the migration of all this percentage of the population towards these areas and taken as settlements [7]. Thus, they are likely to be exposed to lots of coastal risk, particularly coastal flooding, which mainly depends on the change of flood levels, the standard of flood management infrastructure and human exposure to flooding, Which means that people who will be exposed to flood risks in a typical year because of storms would reach six times and fourteen times given 0.5 and 1 meter in Sea level rise by the year 2100 [8], together without another changes and the persons who are displayed by inundating will increase consequently; populations CZs growth as well as migration around the world. Moreover, the sea level rise will lead to disruption, economic loss, loss of human activities which provide an important function. For example, flood protection, waste, nursery areas for fisheries, and harbours managements. Furthermore, 1 meter of SLR intimidates about ½ of the coastal wetlands around the world that are modelled as an important internationally more than 168,000 km sq., besides the worst case of the life loss [9-11].

Even though significant efforts by working groups and research organizations to reduce flood hazards through thier programs, only minor reductions in these risks have been accomplished. This is mostly due to the fact that, as the world's population and urbanization accelerates in tandem with climate change, flood threats are getting more severe [12]. Consequently, it is critical to comprehend and access flood threats, as well as establish strategies for dealing with them through adequate planning and mitigation.Thus, The local officials enable to address the negative effects of elevated sea levels by allowing them to identify both built and biotic communities that are at risk, assess the situation, and develop mitigation strategies throughout using Geographical Information System (GIS) that qualified of producing, interpreting, and submitting sea level rise scenarios, which Changing parameter values in the models of sea level rise to allow the user to run a number of impact scenarios for each model and locality [13]. Moreover, in comparison with other modelling approaches, rules have the advantage that key assumptions can easily be made visible and transparent to users [14].

The main target of this research is to determine and assess the effect of future sea level rise in west coastal area of Libya. Thus, Geographical Information System (GIS), geospatial, and hydrological models will be used as tools to obtain primary calculations of CZ exposure of sea level rise without adaptation or defences, which is a major concern. Furthermore, identification coastal receptors; in terms of society, manufacture, human resource and natural environments that might be influenced by the inundation risk through utilizing feature extraction using an object-based approach in order to obtain image classification. Digital Elevation Models will be employed in this research article to display elevation or three-dimensional topography, DEM is a computer performance of the land surface from topographic parameters for instance, slope, upslope area, and the topographic index, which can be digitally produced [15]. Moreover, used as a useful tool for topographic parameterization of hydrological models, which are the basis for any flood modelling procedure [16], these Digital Elevation Models are most commonly produced from topographic maps, which contain of contour lines that show elevation , as well as could be derived from a set of source data such as; ground surveys, aerial photographs and Stereo-pairs such as with ASTER, SPOT, and IRS satellite imagery [17].

2. Materials and Methods

The study area of this project is located in the northwest of Libya as shown in Figure 1, which is approximately 3062.61543 km², it is bounded from north by the Mediterranean Sea, Tunisia's borders from west, Tripoli city from the eastern side and at a depth of 30 km in the direction of the south from coastal line. This area consists of 2893.29213 km² land and 169.3233 km² Sabkha with 125 km coastline. The main cities in this region are; Az Zawiyah, Sabratah and Zuwara with a population of 573,576 people most of them live on the coastal zone, since they use this area as a settlements, oil refinery plant and harbour for instance; Mellitah Oil & Gas B.V

Libyan branch and Az Zawiyah oil refinery. Moreover, the region depends on seasonal agriculture and animal pastures within the grassland areas, as well as considered as location of the commercial service and many tourist villages and resorts. Therefore, this area is considered a great economic importance. The area investigated is located in geomorphological unit that known as the Jeffara plain, this is a nearly flat area is covered by Quaternary deposits with occasional outcrops of limestone hills belonging to the Al Aziziyah formation. This part is the coastal strip, which is ended by the sea cliffs that are made of formation. This strip extends to the South for a distance ranges from 10 to 20 km and its low topographic areas are covered by sebkha. The study area is contains several sediments, including the Tertiary deposits that represented in the Pliocene rocks, and it appears in the deposits of Al Assah formation, which is made mainly of gravels and sands with local occurrence of recrystallized gypsum. Other geologic formations are also spread in this region that contain Quaternary deposits that including Jeffara formation, which consists mainly of fine materials mostly silt and sand occasionally with gravel an caliche bands. As for the Gargaresh Formation, is the coastal slopes consisting of calcarenite and is economically exploited for the extraction of building stones. Finally, sebkha sediments are appear in the coastal area between the cities of Sabratah and Zuwara, consists of brownish silt with saliferous mixture and the lower band is gypsum sand [18].

Figure. 1 Location of the study area

The present study will be conducted in the northwest coast of Libya, with the goal of determining the impact of future sea level rise in coastal zone through flood zonation mapping and determining flooded regions. The following strategies will be used to attain the aforementioned goals:

ASTER-30m Digital Elevation Model (DEM) superimposed on satellite imagery, which will be utilized as an input data for spatial analysis and derivative products, as well as to outline watershed features of the research region and identify the land-area flooding and determine the vulnerable and risky area using ArcGIS desktop (ArcMap 10.x), this type of data is referred to the Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global at a resolution of 1 arc-second with 30 meters horizontal resolution with grey colour, in this step an eight-side rule was applied as algorithms at one meter level as a scenario according to [8] and [19], which means starting to delineate the areas that are suitable to be flooded by create binary maps using Raster Calculator in Arc Tool box to builds and performs a single Map Algebra idiom in a calculator-like interface. Each raster cell is assigned an output value of 0 or 1 based on the criteria mentioned. Furthermore, if a criterion is met then assigned with value 1 that means suitable and the altitude below the level of sea and the grid cells seems to be inundated, otherwise 0 that means unsuitable and the altitude higher than previously selected sea levels and the grid cells seems to be not inundated.

After having the results of flood hazard models and knowing the most vulnerable area, this will help to make adapting and new plan or/and enhance of the coastal region. In this stage Landsat Enhanced Thematic Mapper ETM+ data was used to create colour composite with band 5,4,3,which is an appropriate for the identification and area estimation [20], this data was utilized to observe the present coastline and Land use map of the region (Receptors) using ENVI 5.3 software, in addition this assessment will implicate future land cover loss and counting of interaction for receptor systems, therefor, in this case features were extracted using object based approach to improve information extraction, accuracy, automated process, speed with the mind to reduce costs for scaling up. this method definitely much faster and found to be very accurate as compared to the manual methods, although the polygons are might be not as clean but the percentage of area that has been mapped as impervious as compared to the manual method is within 88% accuracy levels [21], Different mathematical algorithms was used in this case to segment the image and extract statistic. First process for classifying the image is an unsupervised classification approach, which is very simply just means that let the computer itself run its own algorithms and identify what considers are the unique spectral classes, since again based purely on the spectra and the statistics within each of bands then the analysts have to figure out what each of those computer identified classes actually are. After gained those object assignments, supervised classification approach was second process that runs within each of previous classes to refine them, meaning that initial information were provided to train the algorithms which are then used to reclassify the rest of the hybrid approach, which means analysts know on the ground where specific interested features and then can actually train at the software to look specifically for a very particular reflectance signatures.

After obtaining the map that shows the flood resulting from the scenario of sea level rise at 1 meter, then interacted with all the maps obtained from the previous classification, which produced the receptors represented in urban areas, agricultural areas and plants, roads, beach sand, sabkha, as well as barren lands in order to calculate the affected area of that scenario.

3. Results and Discussion

This research study sheds light on the important role played by topographic data represented by digital elevation models DEMs and their contribution to the study and evaluation of sea level rise using the available modeling in GIS technology, as well as the use of satellite images represented in the Landsat TM image and remote sensing. The result of this study is divided in two parts: The first part relates to the classification of land in the study area that obtained from the previous supervised classification approach, which created the map of receptors represented in urban areas, agricultural areas and plants, roads, beach sand, sabkha, and barren lands, as shown in Figure 2. As well as, all the areas of the receptors will represented in the Table 1.

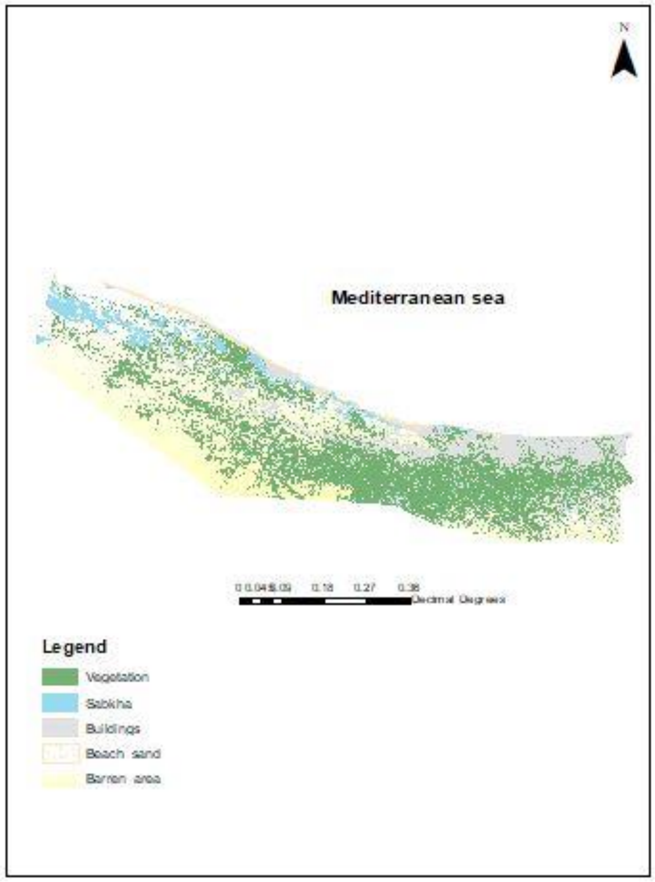

Figure. 2 Receptors of the study area

Table. 1 The areas of the receptors and their percentage related to all area

Receptors	**Areas km^2 / length Km**	**Areas%/ length%**
Urban areas	483.147	15.2
Agricultural and plants areas	1175.4603	36.93
Beach sand	16.9812	0.544
Sabkha	169.3233	5.326
Barren lands	1336.9275	42
Roads	3660.22	-
Total area	3181.8393	-

The second part relates to the results obtained from applying of digital elevation model data using ArcMap software to create slope map in order to describe the topography of the study area and inundation map of sea level rise at one meter. DEM data as shown in Figure 3 showed that the western part of the study area is characterized by its wideness and low terrain, where its height is less than zero below sea level and then gradually increased toward south. Therefore, it is at risk of flooding at this level that reaches to 16-17 km inland until it touches the residential areas and the road network spread along the coast, as well as its width gradually decreases at the same level whenever towards the east with a distance of approximately 83 km from the western borders of the study area with 8 km depth inland. In contrast, the eastern part of the study area as a whole consists of a rocky coast that narrows toward east as a result of the approach of the feet of the western mountain gradually because of the topography and geomorphology of the land, which reaches to 10 meters above sea level at the coastline and gradually increase until reaches to 115 meters above sea level for a distance about 20 km inland, therefore the areas located in the more spacious lands are more vulnerable to flood risks than the areas located on the eastern side of the study area.

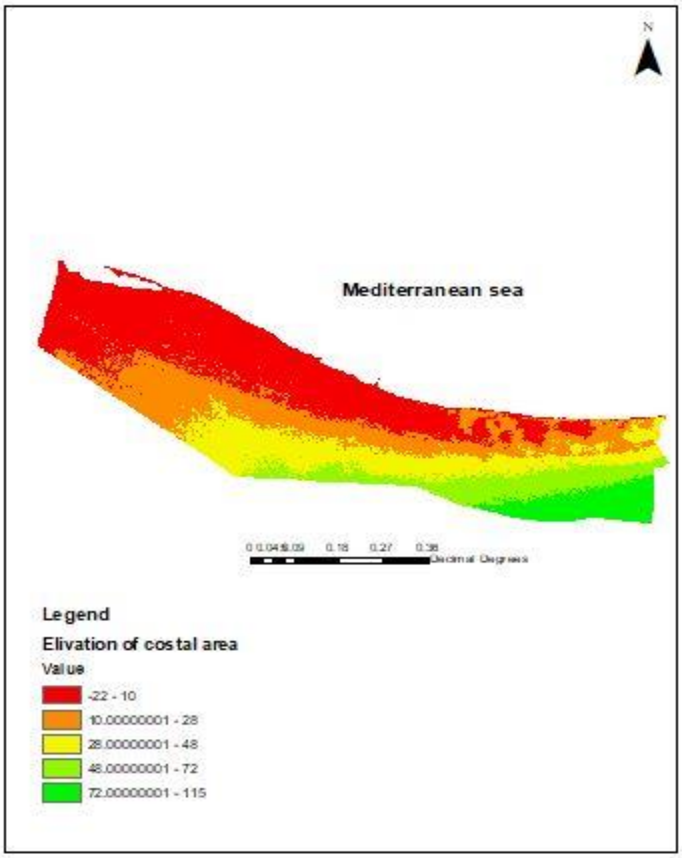

Figure. 3 Slope map of the study area

The scenario, which represented a height of 1 meter from sea level was chosen because it is the highest expected amount in the study [8] by the year 2100 and planning must be carried out within the framework of the worst prediction so as not to encounter unexpected data, especially since climatic variables are now unpredictable. The results are presented in Figure 4, where the percentage of the lands flooded by sea level rise SLR reaches to 16.73% of the total area, which is 532.62 square kilometres.

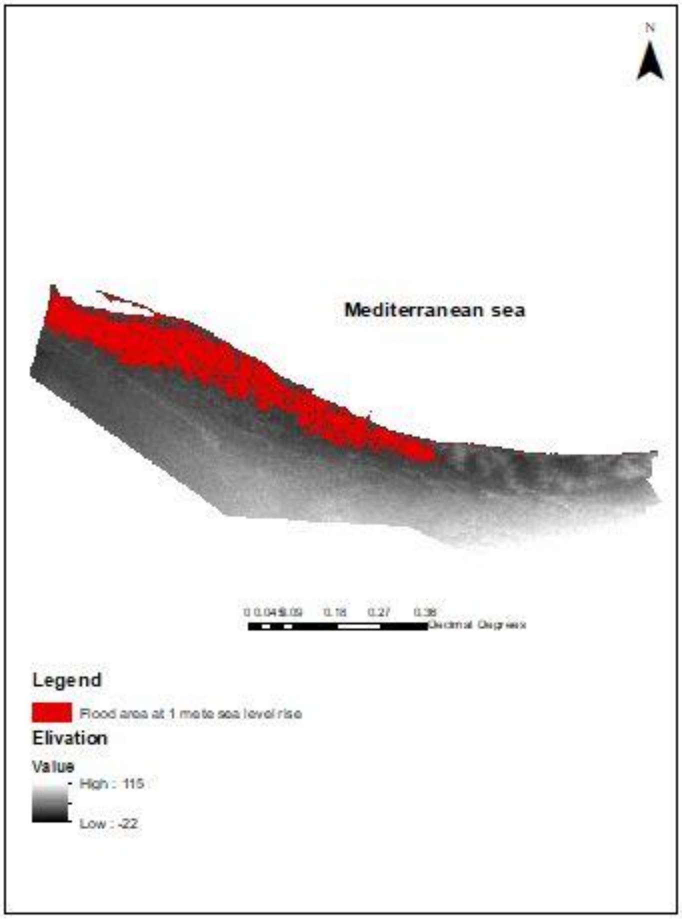

Figure. 4 Flood area at one meter sea level rise

This effect includes all the receptors, which are urban areas, agricultural areas and plants, roads, beach sand, sabkhas, and barren lands, and by using the attribute table from ArcMap table of contents to calculate the intersection of the flooded areas at the level of 1 m with a group of those six previous receptors that produced geographically referenced map of flood risks for each indicator separately as shown in Figures 5, and summarized in Table 2 assuming that no measures or modifications are taken into account to reduce these effects.

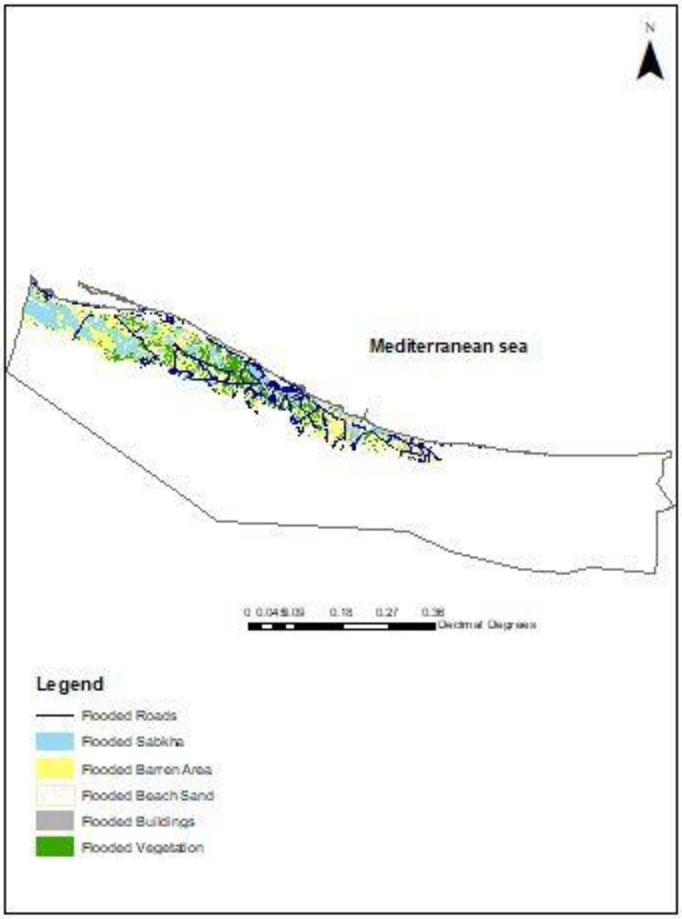

Figure. 5 Map of six flooded receptors at one meter sea level rise

Table. 2 The areas of flooded receptors and their percentage related to the original area of each receptors

Flooded area at 1m SLR	**Areas km^2 / length Km**	**Areas%/ length%**
Urban areas	42.33	8.7
Agricultural and plants areas	114.47	9.7
Beach sand	9.29	54.7
Sabkha	141.28	83.43
Barren lands	198.68	14.86
Roads	373.47	10.2
Total Flooded area	532.62	16.73

Moreover, these effects are concentrated in the western part of the study area much more than the eastern part as shown in Figure 5. Furthermore, these results indicate that the residents of the area are not isolated from the danger posed by the flood at this level and this will pose a threat to their lives even if they try to adapt to this threat unless they are displaced to safer areas that are evident in the eastern part of the study area, which is restricted and supported by a topography with a height of up to 20 km or towards the south that gradually increase in height to reaches from 10 to 28 meters above sea level in order to avoid this danger, this topography is ideal for exceeding the level of risk. Forthermore, this inundation will negatively affect the ecosystem, economic and environmental aspect of land use in the region, not to mention the intrusion of salt water that directly affects the fresh water and the salinization of the lands and increase the areas of the sabkhas and their level.

4. Conclusion

In this study, the model of sea level rise, which depends mainly on topographic data that represented in digital elevation models DEMs and was applied to assess the vulnerability of the northwestern coast of Libya in order to face the effect of sea level rise, taking into account the scenario of 1 m sea level rise by the year 2100. The results of this study are the absolute importance of the data of digital elevation models, as well as their main role in the success of this study, in addition, its role in directly contributing to identifying the most fragile and weak areas and thus adding a positive value to society to confront and adapt this phenomena and help decision makers to contribute in planning and sustainable development. These results also presented the important role played by GIS and remote sensing technology in obtaining accurate spatial information represented in geographically referenced maps of the risks of global sea level rise that enable decision makers to watch and follow up on these risks and develop plans and strategies to protect those areas from the risk of floods. The results obtained in this study, which were presented in the previous chapter, show the magnitude of the disaster, danger, and the weakness of the region especially in the north western part of the study area. Additionally, there are proposed planning alternatives for the regions of the northwestern coast to face the effects of changes from these expected risks, namely stability and adaptation through emergency flood measures, constructing concrete barriers in the sea, limiting migration to these areas, and controlling population growth trends. It is also necessary to prepare for mitigating the effects of this phenomenon in the long run after 2100 through concentrated spread through the development of some areas and the creation of growth poles in the internal and external areas by providing financial resources and information related to this change and setting a vision about future directions for development and policies for the response of residential communities to this change and its expansion.

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