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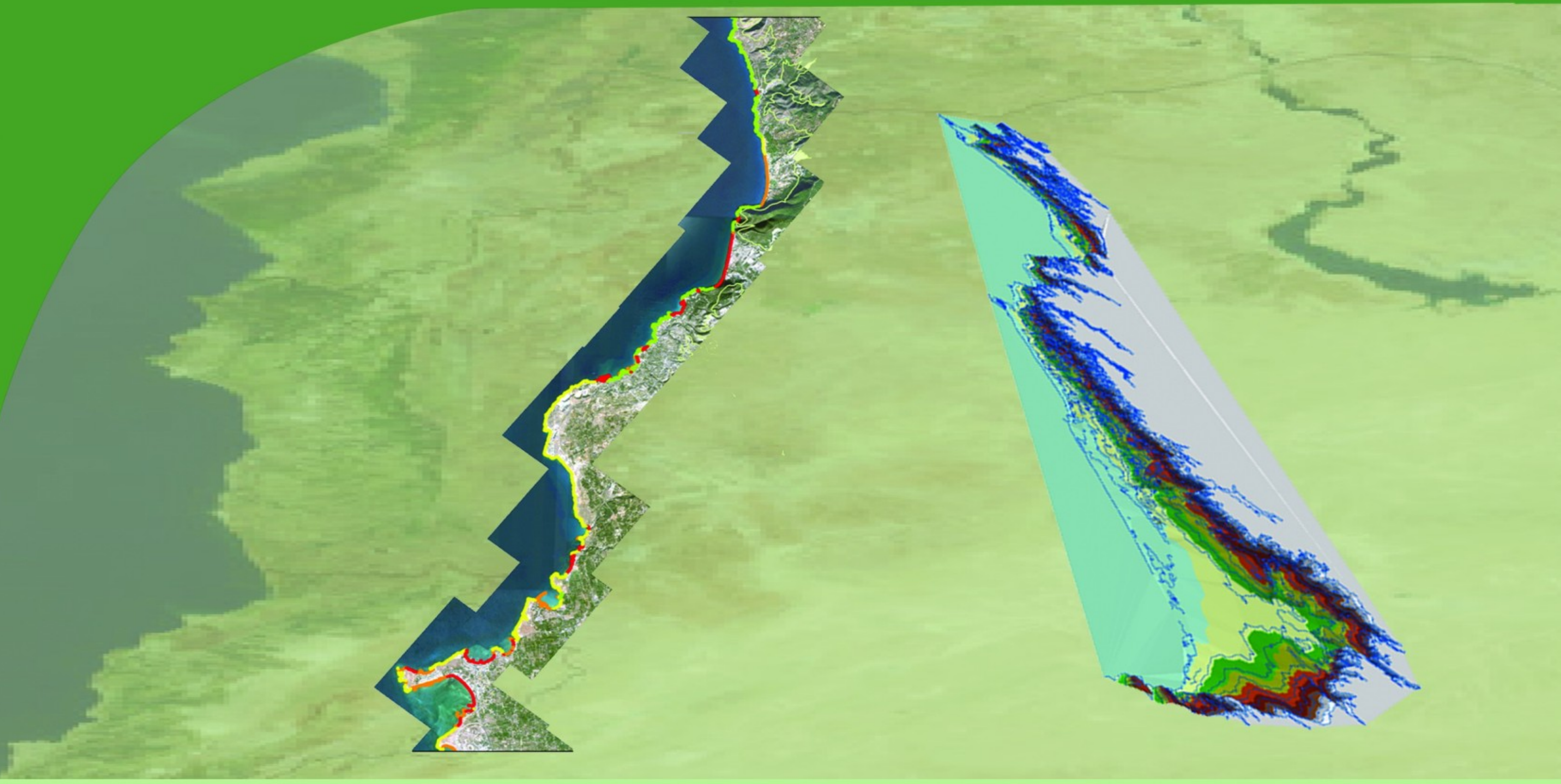
Syrian Sea Level Rise Vulnerability Assessment 2000-2100 (GIS)



Related to the Project Activity

Programs Containing Measures to facilitate Adaptation to Climate Change

Project Title

Enabling activities for preparation of Syria's initial national Communication to the UNFCCC, (Project Nr.00045323).

National Project Director

Dr. Yousef Meslmani

Email: info@inc-sy.org

March 2009

Project Title: "Enabling activities for Preparation of Syria's initial National Communication to UNFCCC", (Project Nr. 00045323).

The project implemented in the ministry of local administration and Environment (MLAE)/General Commission of Environmental Affairs (GCEA), in collaboration with Global Environmental Facility (GEF) and United Nation Development Programm (UNDP) in Syria.

Syrian Sea Level Rise

Vulnerability Assessment

(2000-2100)

(INC-SY_V&A_ Syrian Sea Level Rise-En)

National Project Director:

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March / 2009

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This report has been approved unanimously by the technical committee, during the Technical Workshop which took place on 24/ 03/ 2009 in the Dedeman Hotel Palmyra.

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Introduction

Accelerated Sea Level Rise (SLR) is usually regarded as the most certain consequence of global warming (IPCC WG reports)[1]. SLR has serious physical impacts on coastal areas, mainly characterized by inundation risk and displacement of lowlands and wetlands, increased vulnerability (i.e. coastal erosion, coastal flooding and damage, salinity of aquifers). The increasing coastal inundation vulnerability may lead to substantial socio-economic losses such as the loss of coastal structures, damage to buildings and settlements, dislocation of the population, and the loss of the agricultural production. This study addresses the risk assessment of physical and economical impacts under different SLR scenarios and the analysis of the effects due to SLR (i.e. extended coastal inundation, coastal erosion on populations, land use, etc).

Different scenarios for the estimation of current and forecasted sea level rise in the Mediterranean are being developed[2]. Trends[3] at the western part of the Mediterranean obtained from direct tide-gauge records, taking into consideration the meteorological influence, are ~1.3±0.4 mm.yr^{-1}. It is also agreed that sea level rise is following a non linear pattern[4,5,6]. While it is approved that the SLR is considered a serious risk, changes in extreme sea levels are perhaps more important that mean sea level rise as they pose significantly higher risks to coastal regions. Extremes are related to non-exceptional atmospheric and environmental conditions related to climatic change (extreme weather, wind stress, cyclones, etc). Other parameters, having less impact, to be included in the estimates of SLR are the tide effect, and normal weather conditions. Impacts of tides and impacts of extreme conditions in the Mediterranean could be retrieved form time series measurements at the WWW e.g. Mediterranean ocean forecasting system[7].

The Main objectives of this study are to address questions such as: how much will sea level rise and what effect will that have? How much resources be affected? What will be the impact and damages on the natural ecosystems, human displacement, heavily populated coastal areas at risks, economy, and land use?

While answers are far from simple the main outputs covers: (i) the establishment of different forecasted SLR hazards scenarios (e.g. business as usual, high, best and low estimates); (ii) A risk mapping of the Syrian coastline that would be affected by various amount of SLR in accordance to the different scenarios from low to high (e.g. 1m, 2m – 5m); And (iii) a coastal vulnerability (i.e. coastal area that will be inundated, percentage of land use/ cover that will be eliminated, displacement estimates of human populations away from low-lying areas, forecast on the increased coastal erosion areas, loss costs of developed lowlands and protected areas, probability of saltwater intrusion etc). Terms (scenarios, hazards, risks, and vulnerably) are as defined by the different IPCC WG reports.

Data used covers: Topographic maps 1:50000 used for the extraction of contour lines, and extraction of GCP for image orthorectification; contours are then employed to develop a high accuracy DTM used for the risk assessment of inundated areas; Landsat and Ikonos

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[1] Http://www.ipcc.ch

[2] Tsimplis, M. et al. Changes in the Oceanography of the Mediterranean Sea and their link to Climate Variability. Mediterranean Climate Variability p 227-282. Elsevier, 2006.

[3] Tsimplis, M. et al. Mediterranean sea level trends: atmospheric pressure and wind contribution. Geophys. Res. Lett. 32(20) 2005.

[4] Cracknell, A. Remote sensing and climate change. Springer, 2001.

[5] Hardy, J. Cliamte change: causes, effects, and solutions. Wiley, 2003.

[6] The Scientific basis. IPCC WG1. IPCC, 2001.

[7] http://gnoo.bo.ingv.it/mfs/contents.htm

Images at different time frames (from 1972 to 2005) utilized to delineate the coastline development; land cover land use map, geomorphologic map, population density map, are all used for coastal vulnerability assessment.

Findings are the following:

What are the Syrian coastal zones that could be designated as vulnerable zones to a rising sea level as a consequence of expected climate changes consequences?

In view of the understanding of the different geomorphologic and topographic variability of the coastal, a degree of vulnerability analysis based on different criteria has been carried out to better locate which sectors are more vulnerable to the possible sea level rise (SLR). These criteria include: Geomorphology, Slope (land topography), sea-level rise (SLR).

Moreover, this study evaluates the possible inundated area relative to different sea-level rise scenarios at different rates.

The aim of the present study is to assess the Coastal Vulnerability Index (CVI) incorporating main factors acting on the coastal area (erosion/accretion patterns, topography, subsidence and relative sea level rise). The output is to determine the coastal degree of vulnerability due to SLR. Another aim is to provide measurements of inundated area in relation to different sea-level changes. Possible consequences of sea-level rise and corresponding mitigations are also discussed.

Results reveal that not all of the coastal zones of the Syrian coastal area are vulnerable to accelerated sea-level rise at the same level.

Rising sea levels could have significant long-term impacts on the coastal area especially in areas classified as highly vulnerable. Such impacts include the distribution of ground water salinity and erosion of the narrow and low-lying coastal areas.

1. Physical, Environmental, and Socio-Economic Aspects

The study area has many morphologic, geographical, and societal characteristics, which make its climate scientifically interesting. The purpose of this introduction is to summarize them and to introduce the material extensively discussed in the succeeding of this report.

1.1. Study Area

The Syria coast is located on the North-Eastern Mediterranean coast. The Syrian shoreline spread Long/ Lat from (35.917, 35.92) North (Turkish border) to the South (35.975, 34.633) (Lebanese border). It measures 183km in length, with 90km situated in *Tartous* and 93 in *Lattakia* districts (Figure 1). The coastal zone covers an area of 4200 km^2 distributed over two governments: *Lattakia* in the north (2300 km2; 1139897 inhabitants) and *Tartous* in the south (1900 km^2; 888952 inhabitants, *MOLA* 2007)[8]. Growth rate is estimated to be high (2.58 % for the whole country, NEE 2001). The main land uses/ covers are: cultivated and agricultural lands (225000 hectares), forests (114000 hectares), built up areas (46000 hectares), rocky and sandy seashore (21000 hectares), lakes and marches (7000 hectares), steppe and pastures (5000 hectares).

The coastal region is only about 2% of the total country area, it is inhabited with more than 11% of the total population (total population is about 21.4 millions (2006 estimates, *MOLA* 2007). Nearly 25% of the coastal population lives in four coastal cities located onshore, those are: *Lattakia* (351305 inh.); *Jableh* (66070 inh.); *Banias* (39827 inh.); and *Tartous* (90209 inh.).

[8] MOLA (2007): Records of the Ministry of Local Administration and Environment, Damascus- Syria.

1.2. Physical Aspects

The coastal geomorphology consists of a narrow coastal plain with a variety of ecosystems, it includes but not limited to: wetlands, estuaries, coastal rivers, mountainous and shelf zones.

78% (143Km) of the shoreline is rocky with only about 22% (about 40Km) is sandy beaches. Few gulfs and bays are located along the shoreline.

Four islands (*Arwad*, *Alhbas*, *Alnamil* and *Abo Ali*) are located within the Syrian continental shelf. The largest one being *Arwad*, 3km far from *Tartous*, with an area of 2km2 and a perimeter of 3km. *Arwad* island is heavily populated (45000 inhabitant., MOT 2008)[9]. Main *Arwad* socio-economic activities cover fishing, ship buildings and for its historical records. The other three islands –small in area and uninhabited- are located to the south of *Arwad*.

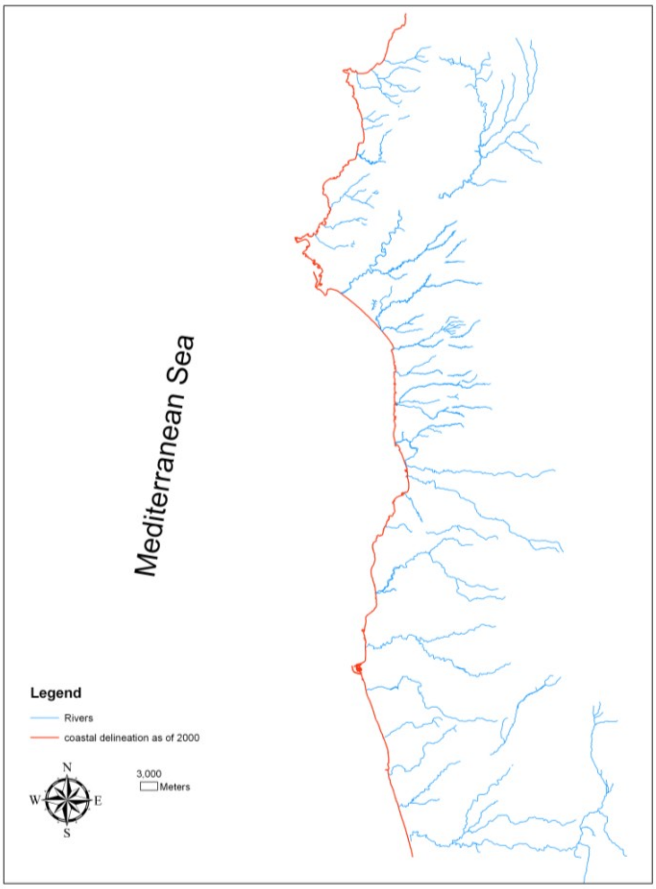

Figure (1): Map of the Syrian coastal area showing coastal delineation and rivers.

1.3. Land Topography

The Syrian coastline has a large area between zero and 5 m elevation. A great part of the beach and coastal flat areas lies between zero and 1 m above mean sea level.

The lower coastal plain varies in width from few meters (*Oum Attiur* area), to several hundred meters (near *Banias* city) and reaches several kilometers (*Lattakia* region and *Alhamidyah* region); Population density is 500 inhabitant/ km^2 (CBS, 2006) [10].

[9] MOT (2003): Official records of the Ministry of Tourism, promotion & marketing Dep't. Damascus, Syria.
[10] CBS (2006): Statistical Abstracts, Central Bureau of Statistics, Syria.

The Northern lower coastal plain is formed of Calcareous and Basalt rocks interrupted with an area of sandy rocks covered with sand and gravel in *Ras Al Bassit*, these land features are repeated again in *Oum Al Ti*ur. Whereas calcareous rocks and river gravel are dominant in the South of *Wadi Kandil* and down in *Burj Islam*. The remaining lower coastal plain is formed of marine sandy rocks with interruptions of sandy/gravel patches around the river estuaries. Two distinctive wide sand dune areas are found: the first, 13km long a few hundred meters width with an elevation above Mean Sea Level (MSL) of 10-15m, is located south of Lattakia between the estuaries of *Alkabir Al-Shimali and Al-Sanawbar* rivers. The second, 12km with elevation of only 4-10m above MSL, is located the long of *Al-Hamidiah* south of *Tartous.*

1.4. Environmental Aspects

The coastal region climate is a Mediterranean humid or subtropical climate, with a gradual increase in rainfall and temperature patterns from west to east and decreases from north to south. This variability also increases from the coastal area to the more elevated mountainous zones in respect to elevation (PAP/ RAC, 1990)[11]. The average annual temperature is 20°c (*Eid*, 2004)[12]. Rainfall occurs mainly during winter, regarding the topographical differences it increases from the coast eastward. Rainfall varies between 800mm.yr-1 (coastal zone) and 1500 mm.yr-1 (mountainous area).

The prevailing wind direction is W to SW, with a common speed varying between 8 to 24 m/ sec for a duration of three days on the average. Winds are usually accompanied with rains -occasional to heavy (GDOP, 2006)[13.] Frequent winds that originate storms are SW oriented and usually last several days, their main hazardous impact is mainly on sea navigation. NE and N winds can be very strong but relatively do not result in high waves in the proximity to the Syrian coast. High waves are mainly combined with the presence of western winds, but their duration is rarely to exceed the 2 days period.

Sea water temperatures measured just below water surface indicates that it range from 14-16°c during winter months and 26-29°c during summer months. Data from the Higher Institute of Marine Research (*Vityaz*, 1992)[14], (*Ovchinnikov et al.,* 1994)[15].

Salinity of the marine water –similar to the eastern Mediterranean Basin- is constantly increasing. The Syrian coastline salinity is related to the increase in evaporation rate due to the global increase in air and sea temperatures and the general reduction in freshwater discharged due to heavy exploitation of rivers currently 20 different dams already are established. Seawater surface salinity has been recorded to be between 37 and 39.8 PPT (*Vityaz* 1992). Additional information of regional sea surface and salinity can be retrieved via the www web.

Sea currents, similar to those found in the Levantine basin, are generally of low speed 13-17 cm/ sec (*Vitayz*, 1992). Following a south to north anticlockwise flow direction. Surface currents, confined to the upper surface layers, may become strong -up to 1m/ sec- when induced by strong wind forces. Surface currents reach its peek between the period October/ November till March. Different sea currents can be retrieved via the www web.

[11] PAP/RAC (1990): Preliminary study of the integrated plan for the Syrian coastal region, P.7 (CCP/1988-1989/SY/PS) Split.

[12] Eid, Y. (2004): Report on predominant climatic situation in the Syrian coast.

[13] GDOP, 2006: Data collected by the General Directorate of Ports

[14] Vitayz, (1992): The Syrian-Russian joint exploration mission in the Eastern Mediterranean Feb. 12 – Mar. 11, 1992.

[15] Ovchinnikov, M. and Abu Samra, F. (1994): Investigations of the winter regime in Syrian Waters of the Eastern Mediterranean Sea. OCEANOLOGY, Vol.34 (3): 428-431.

No observed data regarding the variation of tides along the Syrian coastal area are available. But it can be visually interpreted that the variation of Tide level is of low magnitude. Similar to other tidal variations in the eastern part of the Mediterranean tides are usually considered of less than 0.5m. This low tidal level, combined with slow water currents decrease the dispersion rate of pollutants and increase the impact of pollution on marine life.

No direct measurements of wave heights exist in Syria. But similar to the wave heights found in the eastern part of the Mediterranean waves, mean waves height are around 4-5 m high, with high waves of 7-8m. High wave frequencies are very low and occur only few times during the year.

1.5. Water Resources

Rainfall in the Syrian coastal area is abundant with an average annual rainfall exceeding the 1000mm/ y (CBS, 2006). Rainfall diminishes sharply eastward of the coastal mountains and southward from the Turkish border. Rain, carried by winds from the Mediterranean Sea, occurs between the periods from November to May. The high ridges of the coastal mountains receive most of the rainfall. Frost in the coastal plain is rarely present. The coastal mountain peaks are occasionally covered with snow. While sufficient rainfall supports intensive cultivation in the coastal area, the rainfall variability in time and scale from year to year makes most of the rain-dependent farming at risks.

The coastal area is well known for its richness in water resources. Surface & ground water resources are estimated to be 2235 millions m^3, and the water balance embanked in the coastal dams is estimated to be around 850 millions m^3 (records of the Ministry of Irrigation). This quantity, in addition to the contribution of rivers and wells, is used to irrigate a total of 79629 hectares (*Ghodban*, 1998)[16]. The General Organization of Remote Sensing in Syria has explored the coastal area for its ground water reservoirs and pointed location of major reserves in *Alkabir Al-Shima* river catchment, *Burj Islam (Nahr Al-Arab), Kinsabba, Giganiah, Morran*. Whereas other ground water sources were identified as suitable for bottling (e.g. *Jaobet Al-Rabned, Matta, Bserat Algird and Al-Shagara*); (GORS data)[17].

Wells are distributed along the whole coastal area, causing extensive abuse of freshwater. New digging permissions are decidedly restricted, due to the decrease in ground water level and the intrusion of sea water in different areas along the coast.

Twenty eight coastal rivers discharge into the sea (Figure 1). Most of these rivers are seasonal and usually less than 50 km in length. 20 dams are located on major rivers to divert water for irrigation (DOWR, 2008)[18]. The water exploitation within the coastal area would reduce freshwater discharge into the sea, thus reducing the marine productivity and increasing the water salinity. In addition to the existing rivers numerous springs and streams exist in the coastal areas; their direction is East-West. Many springs and streams end to small seasonal rivers penetrating the lower coastal plain to reach the sea. The amalgamation of rivers and seasonal streams enter into the formation of coastal estuaries. Estuaries are a very important geomorphologic component; they are among the most vulnerable ecosystems impacted by the sea level rise phenomenon.

[16] Ghodban, A., 1998. Water resources and their usage in Syria. Workshop on water resources in Syria. 2-4 May 1998. Supreme Council of Science, Ministry of Higher Education-Syria.
[17] GORS: General Organization for Remote Sensing, Damascus, Syria.
[18] DOWR, 2008: Official records of the Directorate of Water Resources in Lattakia, Ministry of Irrigation, Syria.

Another important component within the coastal area is river valleys which crosses the coastal plain to reach the sea in many places. Valleys are considered vulnerable to inundation due to sea level rise.

17 freshwater springs are present along the shoreline; some of these submarine springs are considered the major source of freshwater to anglers at sea. Main springs are located in *Tartous* governorate, mostly in *Banias* area; only one is discovered recently in *Borj Islam* located to the north area of *Lattakia*. It is evident that the availability of freshwater within the coastal area may provide huge quantities of freshwater resources necessary for domestic and agricultural purposes. In this context, several freshwater pathways have been identified by the Syrian GORS, in *tartous* and *Banias* areas. Freshwater pathways are found to be distributed along the area from 34 55 12 N; 35 54 24 E in the South to 35 13 45 N; 35 58 20 E in the north. The aim was to look for the possibility of trapping the freshwater as they run inland before discharging into the sea (*Carlo et al*., 1998)[19]. The balance between the coastal ground water and sea water is conserved most of the year. But saltwater intrusion is currently occurring in *Al Hamidyeh* coastal plain, close to the border with Lebanon, near *Banias, Al-Bassa* and *north of Lattakia (Dimsarko* area, and northward to *Wadi Kandil*). Salt water intrusion is mainly revealing during the dry months. Uncontrolled over-exploitation of the limited amount of freshwater confined into the aquifer there are considered the main cause for salt water intrusion. Land Stalinization is continuously increasing and contributing to a high level the agricultural productivity.

Small impoundments that accumulate during winter runoffs to are common in the coastal area. They are used as a supplement for summer irrigation.

In a board view, it is obvious that the available water reserve is decreasing with time, due mainly to the decrease in rainfall and to the increased demands on water resources because of the increased human activities and agricultural and developments.

1.6. Socio-Economic Aspects

Most of the economic activities that form the backbone of the Syrian economy are located in the coastal zone. Economic activities include (oil refinery, cement production, agriculture – green house, fruit orchards and intensive farming (CBS 2006). Costal economic contributions total more than 12% to the Gross National Production (*Ibrahim*, 2003)[20]. Coastal population incomes depend on three main sources: agriculture, fisheries, and industrial/tourism.

Out of the cultivated lands 58000 hectares are irrigated and 154000 hectares are non-irrigated and depend on rainfall, with only 13000 hectares are left without exploitation (CBS 2006). The dominant agriculture practices are vegetables, citrus, and olives. Green house farming is heavily practiced in the area where more than 150000 plastic green houses are used for growing tomatoes and cucumber. Agriculture activities support more than 50000 families and thousands of seasonal and part time workers (DOA 2008).

Fisheries are practiced on a small-scale basis. The fishery sector accounts for only 0.002 % of Gross National Product (CBS 2006). The fishery fleet is distributed between 14 fishing harbors along the coast. The largest six harbors are located in: *Tartous*, *Arwad*, *Banias*, *Jableh, Lattakia and Burj Islam*. In addition to the 14 fishing harbors, 4 commercial ports are found (i.e. in *Lattakia, Tartous, Banias and Arwad Island).*

[19] Carlo, T. and Ammar, O., 1998. Groundwater exploration by satellite remote sensing in the Syrian Arab Republic, RSC Series 76, FAO 1998.

[20] Ibrahim, A. (2003): National Diagnostic Analysis (NDA) of Syria, technical report UNEP/MEDU.

A fairly large number of industrial compound are located in the coastal plain those include as for example (*Ibrahim* 2003): Battery factory, wood industry, food processing, beverage, textiles, engines factory, etc. Small scale industrial units such as olive-oil-extractors, thermal power generation station, oil refinery, petroleum pipelines, cement factory are also present. Finally a number of coastal landfills and wastewater discharging points are found.

The coastal area encloses a wide range of tourist complexes. Recently, the coastal area has been put under high level of tourist investments.

2. Sea Level Trends an Overview

Sea level rise poses a major risk for coastal areas. Global sea level rise scenarios for the next century project values confined between 19 and 58 cm, depending on the input assumptions and the global model used (IPCC AR4, 2007)[21]. Different models suggest that sea level rise is expected to increase during the 21st century, mainly due to continuing thermal expansion of the oceanic water mass and the contribution of land ice (IPCC AR4, 2007).

The Mediterranean Sea climate change scenarios are relatively consistent among the global models (IPCC models). Sea level trends for the three longest tide-gauge stations in the Mediterranean are currently in the range of 1.1 to 1.3 mm/ yr (*Tsimplis* and Spencer, 1997)[22], accordingly close to the 1–2 mm/yr lower edge of the estimated global value for sea level rise.

In the last two decades, fast sea level rise was observed within the Mediterranean, especially at the eastern Mediterranean Sea (*Cazenave* et al., 2001[23]; *Fenoglio-Marc*, 2002[24]). Sea level change was linked with changes in observed sea surface temperature (*Cazenave* et al., 2001). The observed sea level values and their temperature forcing have been confirmed by the use of climatological data of oceanic temperatures (*Tsimplis et al.*, 2002)[25]. Furthermore, mass contributions from melting glaciers -Greenland and Antarctica- are likely to affect the future of the Mediterranean Sea level. According to the (IPCC AR4, 2007), the projected global average sea level rise due to mass addition will be in the range from 4 to 23 cm.

The IPCC Fourth Assessment Report (IPCC AR4, 2007) provides a synthesis of recent progress realized in precisely measuring global mean sea level change as well as understanding causes of the observed rise. Satellite altimetry data from Topex/ Poseidon and Jason satellites are being available for more than 15 years (Beckley et al., 2007)[26]. The sea level rise during the past century and the forecasted 21st centaury could be summarized by the synthesis of (*Cazenave* et al., 2008)[27]. The rate of sea level rise is estimated from

[21] IPCC, 2007. Climate change 2008: The physical science basis. Contribution of the Working Group I to the Fourth Assessment report of the Intergovernmental Panel on Climate Change. In: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M., Miller, H.L. (Eds.), Cambridge University Press, Cambridge. p. 996.

[22] Tsimplis, M.N., Spencer, N.E., 1997. Collection and analysis of monthly mean sea level data in the Mediterranean and the Black Sea. J. Coast. Res. 13 (2), 534–544.

[23] Cazenave, A., Cabanes, C., Dominh, K., Mangiarotti, S., 2001. Recent sea level changes in the Mediterranean Sea revealed by TOPEX/POSEIDON satellite altimetry. Geophys. Res. Lett. 28 (8), 1607–1610.

[24] Fenoglio-Marc, L., 2002. Long-term sea level change in the Mediterranean Sea from multi-satelitte altimetry and tide gauges. Phys. Chem. Earth 27, 1419–1431.

[25] Tsimplis, M.N., Rixen, M., 2002. Sea level in the Mediterranean Sea: The contribution of temperature and salinity changes. Geophys. Res. Lett. 29 (3) art. no. 2136.

[26] B.D. Beckley, F.G. Lemoine, S.B. Luthcke, R.D. Ray, N.P. Zelensky, A reassessment of global rise and regional mean sea level trends from TOPEX and Jason-1 altimetry based on revised reference frame and orbits, Geophys. Res. Lett. 34 (2007) L14608, doi:10.1029/2007GL030002.

[27] Cazenave A., Lombard A., Llovel, W., 2008. Present-day sea level rise: A synthesis. C. R. Geoscience xxx (2008).

tide gauges data and from reconstruction methods that combine tide gauge records and regional variability from Topex/Poseidon altimetry. (Figure 2) shows the global mean sea level evolution over the past century (*Cazenave* et al., 2008).

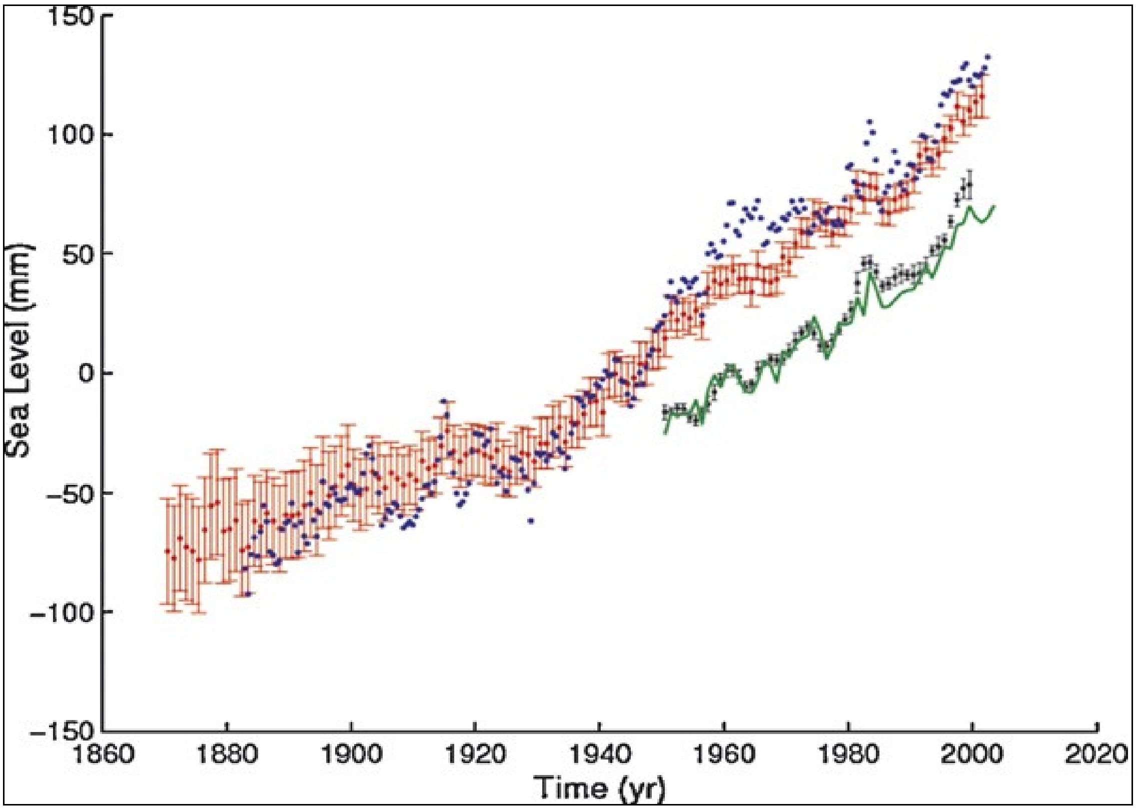

Figure (2): Sea level curve for the 20th century based on different tide gauges data and reconstruction analyses. *Red dots: data from (Church et al., 2006)28; Blue dots: data from (Jevrejeva et al., 2006); Black dots: data from (Holgate et al., 2004)29; Green curve (Cazenave et al., 2008).*

Inter annual/ decadal changes in global mean sea level result from changes in ocean temperature (thermal expansion), in the volume of land ice and in the amount of water stored in terrestrial reservoirs. One of the inter action between temperature and salinity contribution can be seen in (Figure 3). It is based on (Lombard et al., 2008)[30] and using the MERCATOR high-resolution ocean circulation model without assimilation over 1993–2001.

[28] J.A. Church, N.J. White, A 20th century acceleration in global sea level rise, Geophys. Res. Lett. 33 (2006), doi:10.1029/2005GL024826.

[29] S.J. Holgate, P.L.Woodworth, Evidence for enhanced coastal sea level rise during the 1990s, Geophys. Res. Lett. 31 (2004) L07305, doi:10.1029/2004GL019626.

[30] A. Lombard, G. Garric, T. Penduff, J.M. Molines, Regional variability of sea level change using a global ocean model at 1/4° resolution, in revision, Ocean Dyn. (2008).

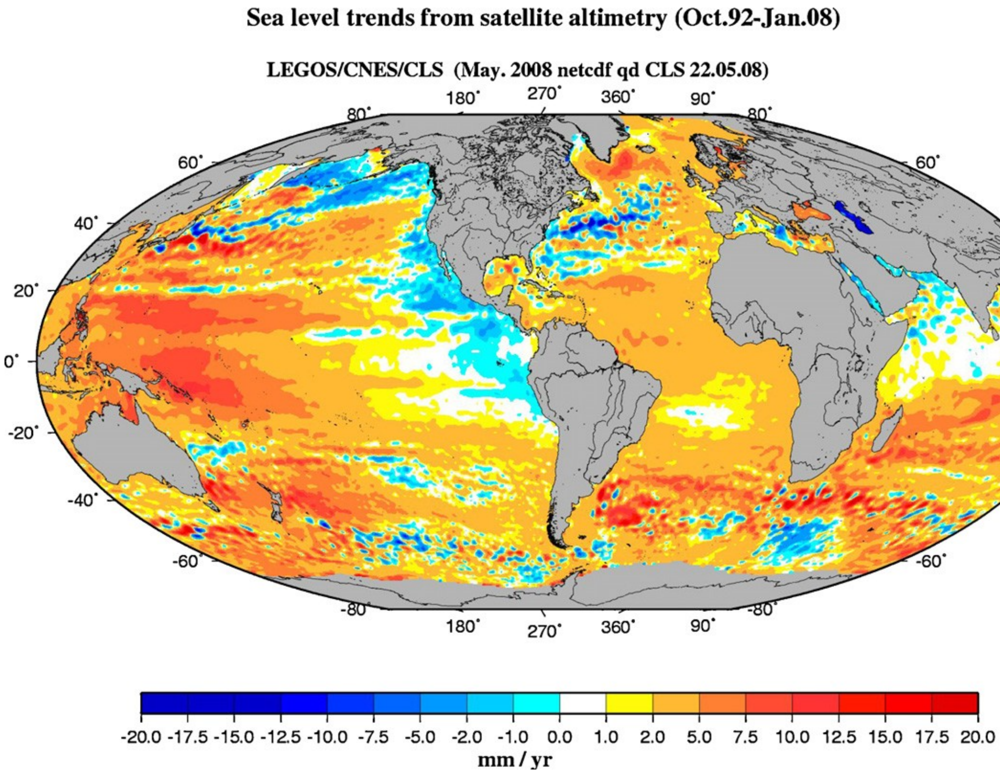

Figure (3): Geographical distribution of linear sea level trends computed over 1993–2008 from multi-satellite altimetry.

3. Mediterranean Sea Level Variability

The Mediterranean Sea (Figure 4), a semi-enclosed basin, extends over 3000 km in longitude and over 1500 km in latitude. It communicates with the Atlantic Ocean through the Strait of Gibraltar and with the Black Sea through the Turkish *Bosphorus* and Dardanelles Straits. The Strait of Sicily separates the western and eastern Mediterranean basins.

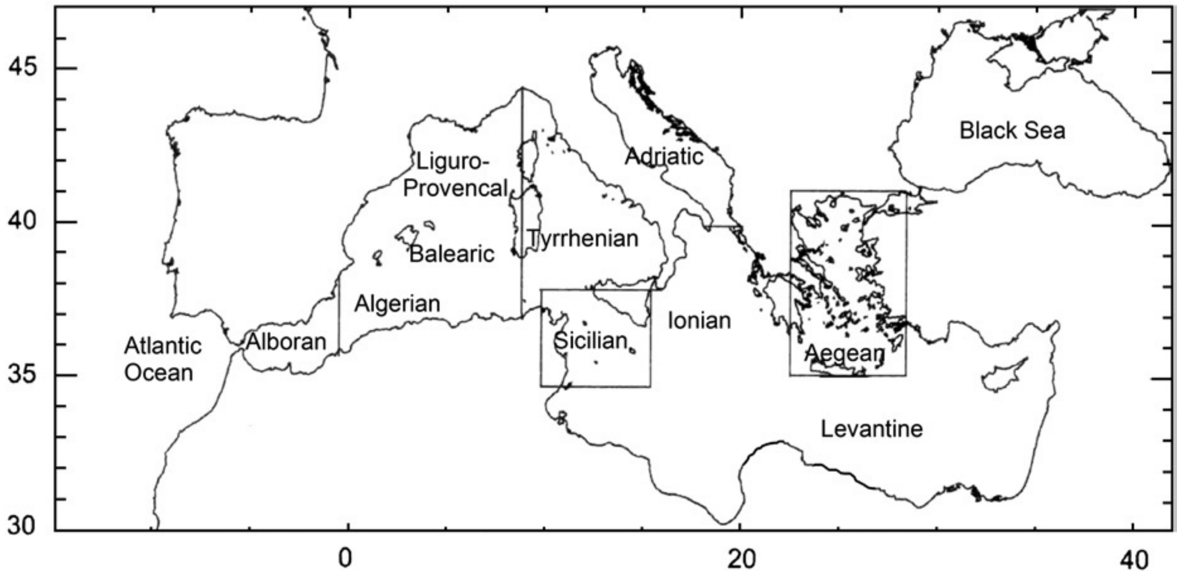

Figure (4): Mediterranean Sea main basins and sub-basins

The Mediterranean Sea general circulation has been described through a series of observational programs and modeling studies over the past two decades (e.g. POEM, PRIMO, EU/ MAST/ MTP/ II), varying at different scales in space (basin-scale, sub-basin and mesoscale) and time (seasonal, inter annual, and decadal). Broadly, the climate of the Mediterranean region is to a large extent forced by planetary scale patterns. Orography and land-sea distribution play an important role establishing the climate at basin scale and its tele-connections with global patterns.

Regional models are being developed at different scales. One of the models outputs (*Tsimplis et al.,* 2008)[31] are shown in figures 5 and 6 (Figure 5 and Figure 6). The inputs for the (*Tsimplis et al*., 2008) model contributing to the expect see level rise due to different factors by 2100 are summarized as follow, at the coastal regions of the predicted *Steric* sea level rise is around 5 cm; Atmospheric pressure increases will also contribute to reducing sea level rise by 1–2 cm; Additional factors such as mass addition of water from melting glaciers and ice-sheets contributions to global sea level rise for the 21st century ranges from 0.01 to 0.13m from continental glaciers, 0.07 to 0.17m from the Greenland and −0.14 to −0.02m from the Antarctica ice-sheets IPCC AR4, 2007). These values would result in a change between −0.07 and 0.18 m in the Mediterranean Sea (*Mitrovica et al*., 2001)[32].

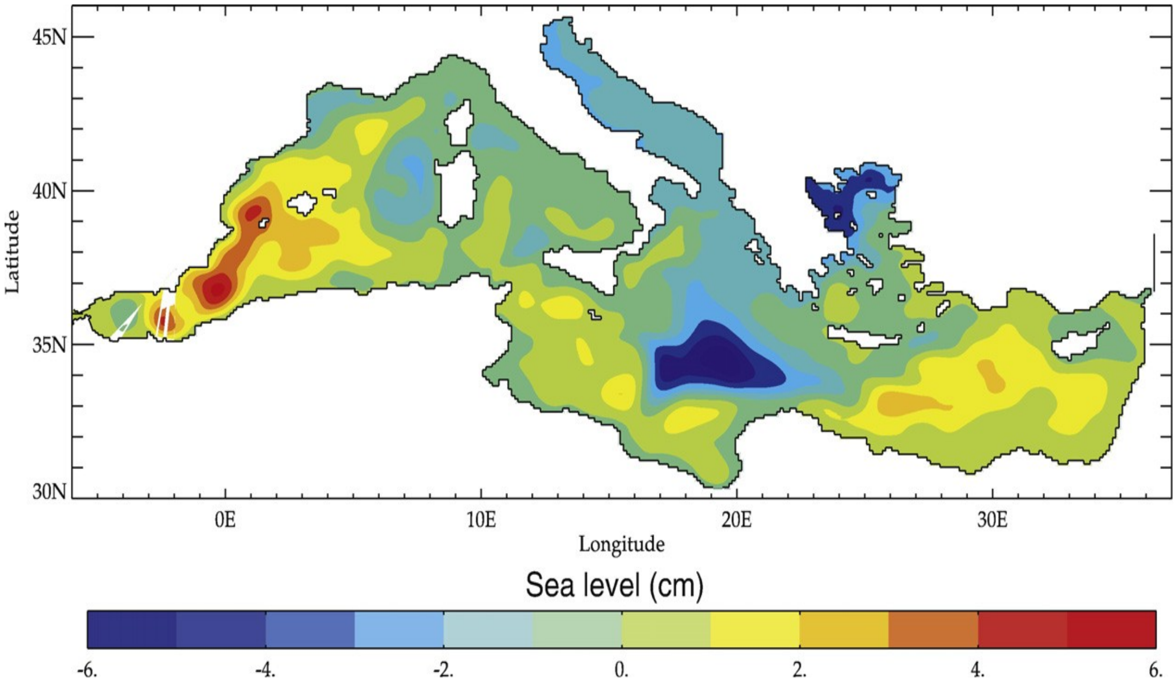

Figure (5): Sea level difference due to variations in oceanic circulation between the periods 2070–2099 and 1961–1990. (*Tsimplis et al*., 2008)

[31] Tsimplis, M.N., Marcos, M., Somot, S., 2008, 21st century Mediterranean sea level rise: Steric and atmospheric pressure contributions from a regional model. Global and Planetary Change 63 (2008) 105–111, doi:10.1016/j.gloplacha.2007.09.006

[32] Mitrovica, J.X., Tamisiea, M.E., Davis, J.L., Milne, G.A., 2001. Recent mass balance of polar ice sheets inferred from patterns of global sea-level change. Nature 409 (6823), 1026–1029.

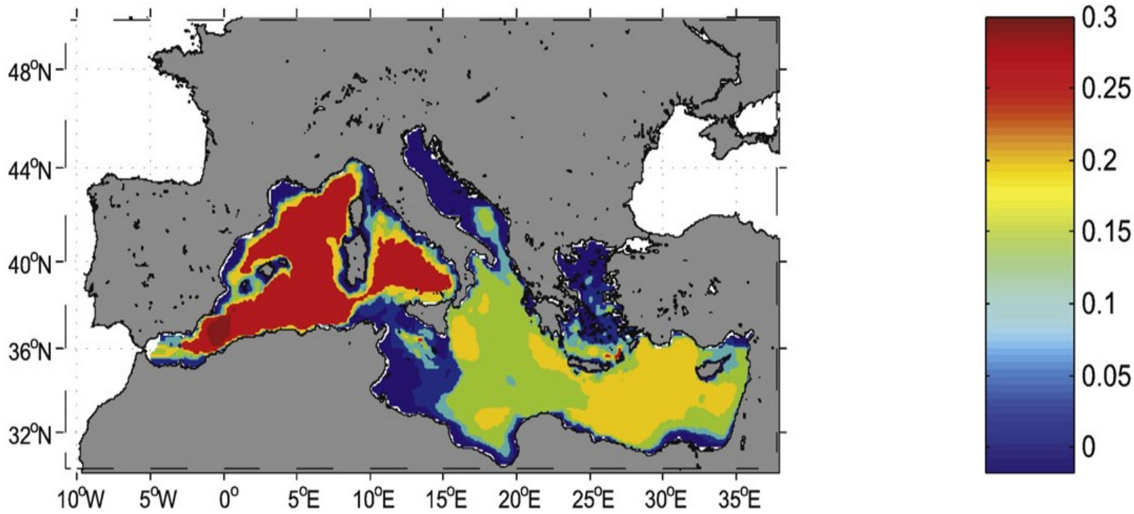

Figure (6):. Steric sea level differences for the periods between the periods 1961–1990 and 2070–2099 (Tsimplis et al., 2008).

3.1. Current and Forecasted Eastern Mediterranean Sea Level Trends

Our aim is to identify the main sea level variability in the eastern Mediterranean Sea circulation patterns especially in relation to long-term trends in water mass characteristics, sea level changes and the Eastern Mediterranean Transient (EMT) event. Based on existing literature the estimation of total sea level was primarily achieved by means of tide gauge stations located in coast worldwide. Where it is clear that trends vary considerably with location, accepted global range are between 1–2 mm/year for higher values and about 0.5 mm/ year for lower values (Figure 7) (*Criado-Aldeanueva et al*., 2008)[33].

The launch in 1991 of ERS-1 and TOPEX/ POSEIDON (T/ P) satellites started the altimetry missions, which provide open ocean sea level data shedding new possibilities to sea level studies. Detailed major changes in the Mediterranean surface circulation at basin and sub-basin scales are reported by (*Cazenave et al*. 2002)[34], merging 6 years (1993–1998) of T/ P data with ERS-1 data (1992 to 1996). (*Cazenave et al*., 2002) have reported a mean sea level rise of approximately 7±1.5 mm/year in the Mediterranean Sea, although its spatial distribution is not uniform: the Levantine basin is rising at a rate of 25–30 mm/ year; the Ionian Sea is falling 15–20 mm/ year. In the western basin, sea level trends are significantly lower, some regions rising and others falling. On the other hand a longer data series—9 years of T/ P, ERS-1 and ERS-2 merged data, was used by (*Fenoglio et al.,* 2002)[35] and found more moderate trends: 2.2 mm/ year for the entire Mediterranean, with lower values in the western basin (about 0.4 mm/ year), higher in the eastern (some 9.3 mm/ year) and, again, a sharp decrease of 11.9 mm/ year in the Ionian Sea. In this context the availability of almost 15 years of altimetry data have reported a significant change in the sea level trend from mid-1999 in certain regions of the Mediterranean. However, it is acclaimed that further research is needed in order to accurately determine trend variability (Vigo et al., 2005)[36].

33 Criado-Aldeanueva, F., Del Río Vera, J., García-Lafuente, J.,. Steric and mass-induced Mediterranean Sea level trends from 14 years of altimetry data. Global and Planetary Change 60 (2008) 563–575

34 Cazenave, A., Bonnefond, P., Mercier, F., Dominh, K., Toumazou, V., 2002. Sea level variations in the Mediterranean Sea and Black Sea from satellite altimetry and tide gauges. Global and Planetary Change 34, 59–86.

35 Fenoglio-Marc, L., 2002. Long-term sea level change in the Mediterranean Sea from multi-satellite altimetry and tide gauges. Physics and Chemistry of the Earth 27, 1419–1431.

36 Vigo, I., García, D., Chao, B.F., 2005. Change of sea level trend in the Mediterranean and Black seas. Journal of Marine Research 63, 1085–110

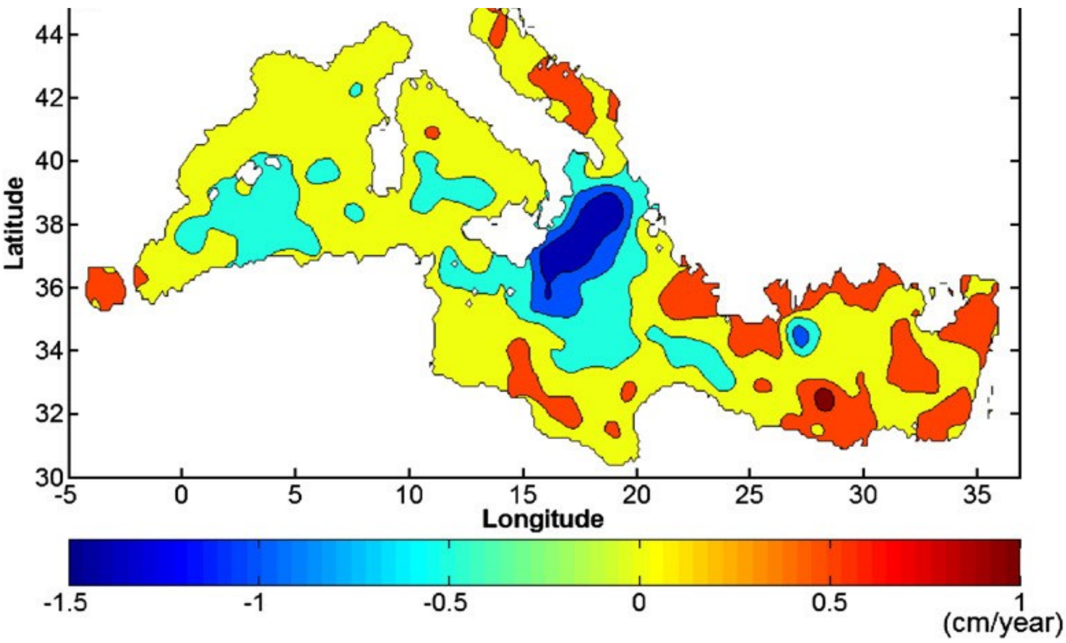

Figure (7): Overall sea level trends after (*Criado-Aldeanueva et al.*, 2008)

4. Material and Methods

4.1. Material

The study required the acquisition and processing of the below data.

4.1.1. Topography and DEM

For the assessment of the projected SLR scenarios the study has used the topographic map at 1:50000 with 10m to 20m contour interval to generate contour. A digital elevation model (DEM) was generated from the interpolation of the elevation data by triangular irregular network (TIN). Additional ground control points (GCPs) (Bench marks, and available ground elevations) were used as mass points within the DEM calculation. The **SRTM37 data with an accuracy of 30m was used as a feedback were ground control points** were missing, especial in the delineation of valleys. The DEM is constructed using the Arc GIS software for the entire coastal zone (Figure 12). The horizontal resolution of the DEM was 10 m, the vertical accuracy was between 5-10m. Even though this accuracy is considered low, a database of ground control points measured by a ground positioning system should be collected for accurate analysis. The required DEM resolution for sea level rise modeling should not exceed the 2-5 m resolution.

4.1.2. Land use

The Land use/cover Map was developed by GORS during COLD project using visual interpretation of Multispectral Landsat Satellite images using FAO Legend. This LUC map is used for overlay and the risk assessment.

4.1.3. Satellite Data

Landsat scenes covering the entire study area are used covering different time frame. While the study area spreads over two scenes, these correspond to the path 174/35 and 175/ 36 and cover a time period of 16 years. Landsat Scenes acquired in 1987 by Thematic Mapper (TM) sensor, whereas two sets of scene were acquired on 2000 and 2005 by the

[37] SRTM WEB

sensor Enhanced Thematic Mapper (ETM+) sensor. All images were mosaicked and merged with the panchromatic band to extract orthorectified Images with 15m spatial resolution. Images were registered and defined within the UTM zone 37N coordinate system. Tide differences between the different images were neglected due to the missing data availability of tide variation from ground measurements. Visual interpretation was applied to delineate the coastline in 1987, 2000 and 2005.

An IKONOS image covering the entire area, 1m spatial resolution taken in 2006 was used for the visual interpretation of coastal geomorphology. The IKONOS image was registered also under UTM zone 37N.

4.1.4. Broad Data

Different forms of data were collected. These include 1:50000 scale topographic maps and 1/ 200.000 geologic maps 1:500.000 soil map, 1:1000.000 geomorphologic map. Maps were used in the assessing or development of the project data (e.g. extraction of wells and streams from the topographic maps).

4.2. Data Processing and Analysis

During this primarily phase of the project the GIS environment was used to extract information, classify and overlay of spatial information. Change detection using multi-temporal satellite data involves preprocessing, classification and application of the change detection techniques. Analysis can be classified into the following topics:

4.2.1. Image Preprocessing

For each Land Sat scene, the three Bands within the visible domain -i.e. Red, Green, and Blue- are combined in a single image (RGB image). These images are then subjected to geometric correction and change detection analysis.

Geometric correction of remote sensing images is essential and critical prerequisites primarily for change detection analysis and secondary for visual interpretation; since it is crucial to have maximum overlay between different images and vector GIS data. Georeferencing and geometric correction for all images was carried. All images were registered to the topographic maps using the Universal Transverse Mercator Zone 37N Projection.

Image to map registration for the 1987, 2000 and 2005 Landsat scenes was done using 20 well distributed valid ground control points (GCPs) and a second order polynomial transformation. RMS was kept within the 20 m range for all images.

The Landsat image for the year 2005 was utilized as a reference to rectify the other images to the same coordinate (UTM Zone 37N) system through image to image registration using 20 GCPs. Image to image registration was also carried for the IKONOS images using 200 GCPs along the coastal area. RMS was equal to 2 m.

Landsat rectified images were used for erosion/accretion detection along the coastal area. The use of these images was very useful in investigating the coastal ecosystem/ landscape change over the entire study area. Even though the resolution is of the 15-30m it is feasible to acquire a general idea on the coastal development over the 4 decades. Evaluation results of the images for erosion/accretion detection are discussed in the change detection section of this report.

4.2.2. Change Analysis

By definition change detection by remote sensing involves the use of multi-temporal images to categorize primarily changes in land use/ cover between the different dates of imaging acquisition. Within this study the change detection technique was used to detect primary changes over the development of the shoreline limits at different time frames using topographic and Land Sat images. Since it is not within the scope of this study to undertake change detection and erosion/ accretion analysis, the approach was made as reasonably to give a general idea of the shoreline development. It is however for an expert point of view to undertake a serious erosion accretion analysis over the shoreline especially in areas that will be defined as vulnerable and would be most impacted by sea level rise.

Since this analysis was out of the scoop of the current study and due to unavailability of accurate information on the status of erosion/ accretion over the Syrian coastline. The change detection technique was used to outline only the area of changes, with a general overview on the type and volume of change. No figures or estimates are given due to the non possibility to undertake and engage field investigation and validation. Our aim is to take advantage of the available information, obtain realistic and primarily assessment for changes of the coastline temporal variations.

This direct change detection was carried by delineating the shoreline limits form the multiple images and topographic maps. This approach depends on making a direct comparison of the coastal and land discrimination through visual interpretation and supervised classification of the Landsat thermal band. Thermal band are well known for their ability to highly differentiate water bodies from their land surrounding.

Results of this step were successful in yielding broad information of change. It was found that major enlargement over the shoreline were manmade (e.g. development of coastal urban areas such as harbor, docks, etc). No visible accretion caused by sediment deposit was visible. Similar to natural accretion erosion was of low magnitude. Erosion and accretion are discussed in the Erosion/ Accretion Patterns part of this report. Shown in (Figure 8) is model scheme of the implemented methodology.

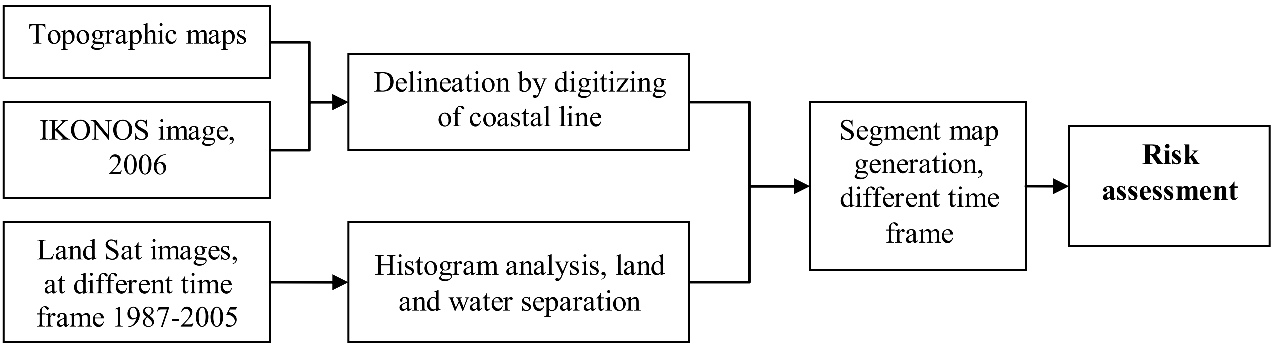

Figure (8): Increased coastal erosion model

4.2.3. Further research

Qualitative and quantitative change detection techniques are suggested if further investigation is implemented. Qualitative and quantitative change detection techniques my include Band Differencing, Bands Overlay, multi-temporal classification and Principal Component Analysis PCA.

4.3. Erosion and Accretion

No local data on waves measured was available to hypothesize the predominant wave directions, nor the availability wave gauge to be used in this study. Studies of the shoreline position and sediment budget along the coastline in addition to coastal erosion were missing. Based of the change analysis technique used previously the pattern of erosion versus accretion was fixed to ± 7.5 m (interpreted as no significant or no change) for the entire coastal area. This pattern is to be used in the assessment of Costal Vulnerability Index (CVI).

4.3.1. Visual Interpretation

Lack of precise geomorphologic classification of the coastal area required the implementation of a geomorphologic map from the available information and the visual interpretation of the IKONOS image. Visual interpretation, by definition, involves identification and delineation of land cover/ use types. Visual interpretation has been made by using IKONOS image, Landsat images, topographic maps, contour lines, soil and geological maps. Field observations and validation were not established.

The coastal geomorphologic classification was based on the general coastal geomorphology and was adopted as much as possible to the requirement of the (CVI) classification. With the absence of field observations and validations, in some cases, generalization has been applied so as to minimize confusion of similar features and to obtain faithful delineation of coastal geomorphology. The geomorphologic classes are show in table 1:

Table (1): Geomorphologic Classes

Coastal Geomorphology		
Class name	**Sub-Class**	**ID**
Beaches (Sandy)	Coastal (wash over)	11
	Medium (Sand Dunes)	12
	High (> 5m continues Sand Dune)	13
	Mixed	14
Rocky Coasts	Flat land	21
	Hilly land	22
	Steep	23
	Mountainous	24
	Cliffs	25
Deltas, Estuary, and Wetlands	Marsh (grass, shrub, forested, etc); Cultivated	30
Artificial (Including protected)	Harbor	41
	Seawall	42
	Breakwater	43
	Dams	44
	Builtup	45
Islands	Islands, rocks, cliffs	50

The coastal geomorphologic assessment was implemented within the coastal shoreline. It is crucial that a full more detailed geomorphologic assessment is implemented. The geomorphologic map is shown in (Figure 9).

4.3.2. Accuracy Assessment Requirements

It is essential to validate the main outputs yielded by Remote Sensing analysis and image classification. Accuracy assessments typically involve the generation of a number of random locations or even manual defined locations which are then verified by field check (e.g. field validation could be handled with assistance of the GPS). The degree of accuracy in the classification is computed statistically by comparing measurements in the field to those in the classified image or map. Using statistical technique, the overall classification accuracy is computed, error matrix is the main output of the analysis.

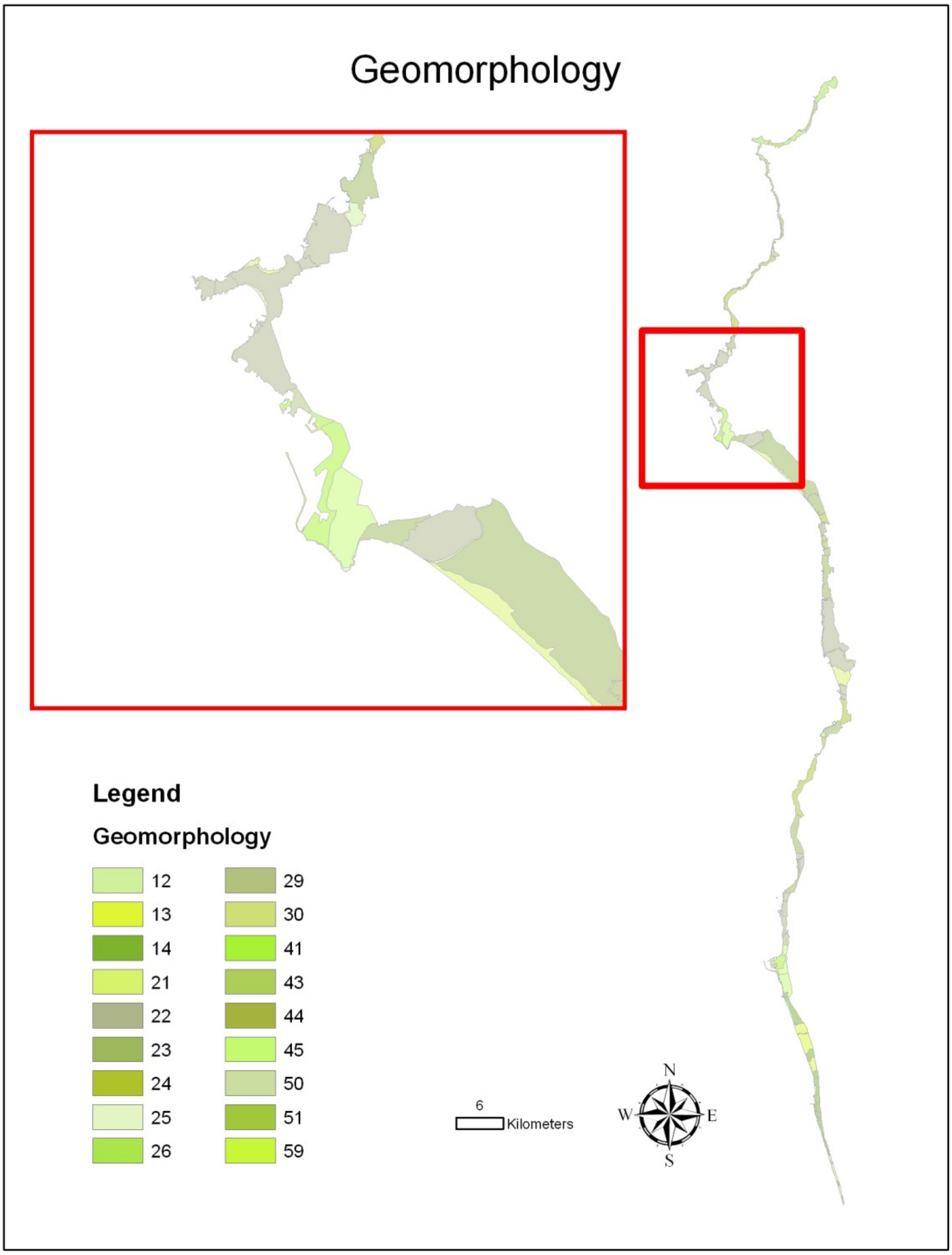

Figure (9): Geomorphological Map extracted from Ikonos images

5. Sea Level Rise Scenarios

Appraisal of the (IPCC) reports was designed to acquire a comprehensive knowledge of the possible effects of climate change impacts on sea level trends. The latest sets of (IPCC) assessments reports (IPCC AR4, 2007) in addition to the studies carried within the Mediterranean, refer to section 2 of this report, were used to evaluate possible sea level scenarios. The base scenario was the mean of the three (IPCC) scenarios. According to the climate change scenario results, the projected values of sea level for the year 2100 are 32 to 56 cm on average with a maximum projection of 95 cm with a mean of 60 cm. Because of the relatively broad range of results, indicating variable trends, projections used is this study are considered as the general projections on the average sea level rise in the Northern-Eastern part of the Mediterranean. Other scenarios also took into consideration seasonal variability. The projections used in the present report are to be considered as the projected values for sea level rise scenarios for the year 2100. The scenarios of future sea level were to calculate the projected values for a given year from present. The projected values were obtained by multiplying the estimated trend in $cm.yr^{-1}$by the number of years from present. E.g. To calculate the increase in 2100 for a scenario of $0.6cm.yr^{-}1$ based on the shoreline delineation of 2000 multiply 0.6 by 100, the expected increase is 60 cm. The highest scenario is chosen as the upper limit of accelerated sea level rise (pessimistic) and the lowest scenario as the lower limit (optimistic). According to the different scenario results, the projected sea level rises are 0.6, cm on average with a maximum projection of 5-7.5 m.

5.1. Seasonal Variations

Annual and seasonal variations can be produced by a variety of local oceanographic and climatic processes; these include changes in water temperature, atmospheric pressures, and winds. It is believed that high tides along the Syrian coast may raise water levels by about 50 cm beyond normal Mean Sea Level (MSL). Medium wave height is around 2 m. Extreme waves, due to extreme stormy weather, may reach the 6-7 meter high. These seasonal variations intermittently play a role in accelerating beach erosion, flooding across the low lying lands. Seasonal and sea level effects are shown in Figure 10. Tidal records in addition to knowledge of monthly and seasonal variations are essential because inundations are more likely to happen during periods of higher mean sea level.

5.1.1. Tides variations

Tides experienced at the Syrian coastal area are not defined. No based daily observations are available, information on tide category, amplitude and harmony are crucial to further elaborate on the sea level variability.

5.1.2. Monthly Mean Sea Level Variations

The climatological seasonal cycle are essential and should be considered. Rainfall and river discharges minimum and maximum should be well acknowledged. However since no information were available, no such implementation of these variation could be processed.

5.1.3. Seasonal Cycle

Monthly mean sea level should be acquired. This monthly average will significantly be used to eliminate the influences of tidal variability. The monthly mean is also effective in reducing all effects with period less than a month.

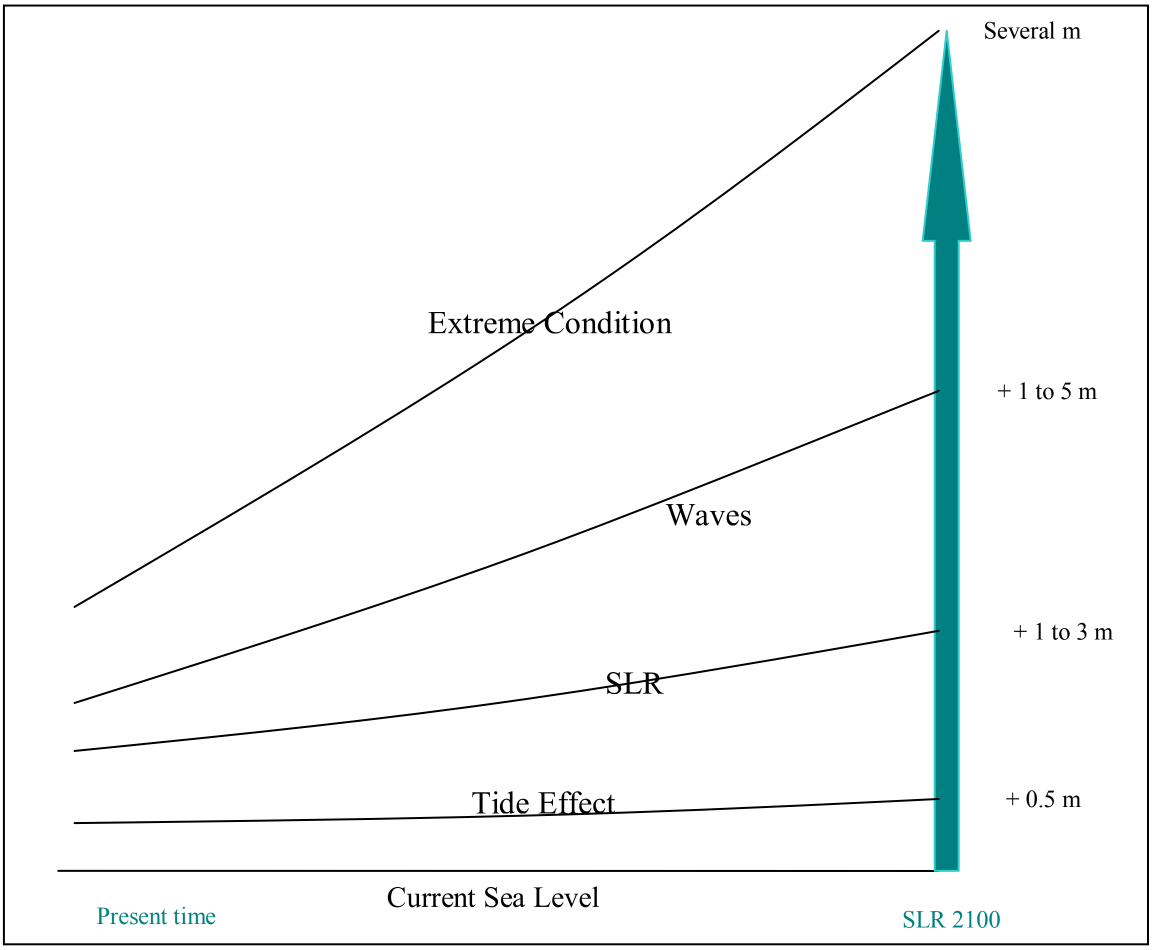

Figure (10): SLR scenario Effects (Estimates are as adopted within this report)

Continues assessments of the (IPCC) were designed to provide a comprehensive survey of the state of knowledge about climate change for use at national and international scales. The latest reports of IPCC (IPCC AR4, 2007) strengthened previous findings. The historic sea level rise at the Syrian coastal area is not available due to lack of studies. This study shall adhere to IPCC mean, i.e. 60 cm. To develop the total sea level rise projections for a given location, the scenarios of future sea level were obtained for this study by adding the projected values to different given primarily seasonal and monthly variations. SLR scenarios are shown in table 2.

Table (2): Selected Sea level rise scenarios:

SLR Scenarios

	Trend in cm.yr-1	Variation 2000-2100 in cm	Reference
Very low	0.6	60	IPCC mean
Low risk	0.9	90	IPCC max
Moderate risk	1.3	130	-
Intermediate risk	1.9	1.9	IPCC + Seasonal Variation
High risk	2.5	250	-
Extreme risk	>5	500 up to 750	-

5.2. Possible Consequences of Sea-Level Rise

Similar to different coastal area in the Mediterranean it is rational that parts of the Syrian coastline are designated as vulnerable to a rising sea level as a consequence of the expected climate changes. The SLR would have physical, biological and socio-economic impacts. These include impacts on beaches, urban areas, agriculture zones, super and infrastructures, salt-water intrusion, as well as an increase in salinity. The socioeconomic impact of sea-level rise on coastal lowlands would vary depending on the degree of land use and development activities.

SLR -as a result- has serious physical impacts in the coastal areas, these are mainly characterized by: (1) inundation and displacement of lowlands and wetlands, (2) increased salinity of aquifers, (3) increased coastal erosion, and (4) increased coastal flooding and damage.

Extended coastal inundation would be a serious problem not only to the urban coastal areas but also for wetlands and coastal farmland area, and Small Island. The increasing coastal inundation may lead to substantial socio-economic losses such as the loss of coastal structures, damage to buildings and settlements, dislocation of the population, and the loss of the agricultural production. This project addresses the risk assessment of physical and economical impacts under different SLR scenarios and the analysis of the effects due to SLR (i.e. extended coastal inundation, coastal erosion, floods, and increased salinity) on populations, land use, etc.

Rising sea level will potentially affects all coastal environments at varying degrees. The most vulnerable being the sandy beaches, coastal wetlands, deltaic coasts, and small islands. SLR erodes beaches by increasing offshore and long shore loss of sediment, directly inundating or submerging marshes and other low lying lands, increasing the salinity of estuaries and aquifers, raising coastal water tables, and exacerbating coastal flooding. Coastal zones cost vulnerability is characterized by the potential displacement of millions of people. SLR ecological and economical impacts are characterized by the vanishing of low-lying lands, deltas, and islands. Sever consequences on human settlements located therein is portended. Loss of coastal wetlands would be significant. Erosion of beaches will mostly threat tourist activities and would require expensive beachfront development and maintenance.

Investigating risks and impacts assessment in coastal ecosystem is probably the most difficult when compared to other environmental ecosystems. This is due to the extreme variety of phenomena that can integrate.

The objectives of the rest of this report are: the determination of Coastal Vulnerability Index (CVI), which in turn is of great help to assess consequences and adaptation to impacts of accelerated sea-level rise. And the Evaluation of potential coastal inundation risk due to based on different scenarios. Finally, assessment of impacts that would reign over different biological and physical components.

Vulnerability analysis is categorized into five classes from varying from very low to very high-risk areas. Affected areas due to sea-level rise inundation are mapped using GIS and topographical modeling. In terms of impacts, impacts on agriculture, conditions of salinity, available fresh water resources are considered.

6. Coastal Inundation

Understanding of the consequence of inundation and its spreading on the coastal area requires a model of the inundated area as a result of high sea water rise. For this purpose, geospatial technology has the advantage to model the spatial spreading of the inundation. The model of the coastal inundation is to be generated using GIS raster interpolation, neighborhood operation, and iteration calculation. Potential risk assessment is evaluated, in the final section, on population, urban areas, and land cover/use and their economic values.

6.1. GIS Modeling of Sea-Level Rise Induced Inundation

The potential impacts of rising sea level for year 2100 have been recognized as a potential future hazard. Availability of detailed information in elevation data is crucial for the evaluation of hazard assessments. The use of existing information, namely topographical and collected (GCP) is considered the most appropriate way to simulate shoreline inundation due to SLR. The primary aim of this part is to develop a simple, easily applicable, (GIS) model for simulating coastal inundation. The model would take the available information, such as topographic maps and the digitized DEM. Shown in (Figure 11) is the inundation model schema.

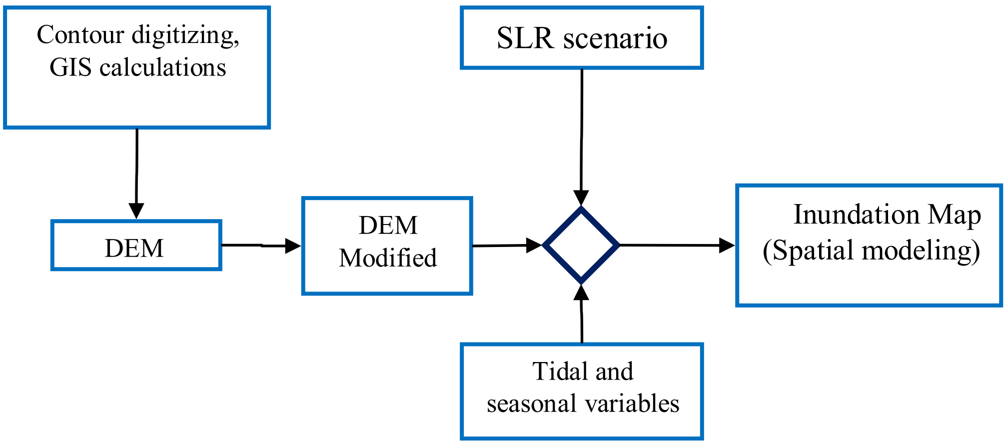

Figure (11): Inundation Model

(GIS) modeling allow the combination of different data (e.g. topography, geomorphology, geology, land use/ cover data). However, issues of uncertainty are considered as one of the main limitation within (GIS) modeling. Different variables could be addressed during the implementation of any model application to minimize uncertainties. The following variables were addressed within the current model:

- Proper definition of parameter values, namely the rate of sea-level rise.
- Maintenance of data-resolution and accuracy, RMS was restrained as much as possible during image registration, refers to data the material and method section of this report.

The collection of high spatial resolution data, in particular elevation data, is costly and time consuming to be applied over large areas. The GIS model developed is considered suitable for providing first estimates of potential shoreline inundation, based on the current available information.

The DEM shown as an Arc scene layout in (Figure 12) was generated using (GIS) spatial analysis. Contour lines of 10 and 20 m interval in additional GCPs used as mass-points were the inputs during the generation of the Triangular Irregular Networks (TIN) file. The TIN covers altitude from 0 to 100 m. The TIN was converted in a 10x10m resolution grid raster.

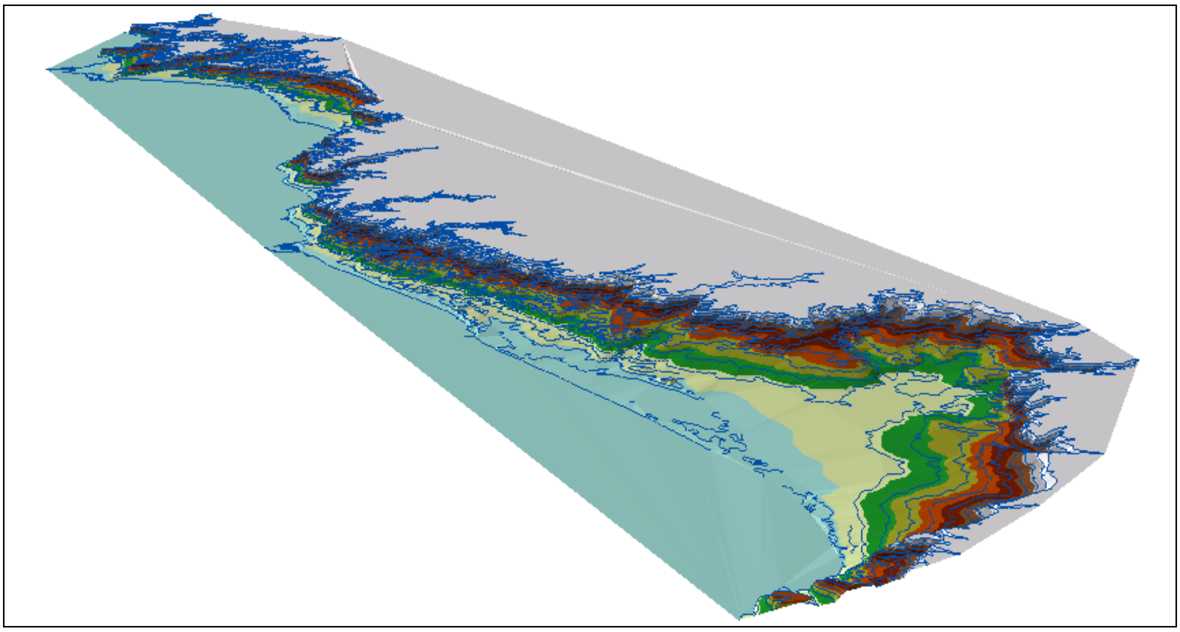

Figure (12): DEM of the Syrian Coast

Six different scenarios of SLR changes are implemented (TABLE). For modeling the spatial extent of shoreline change a Geographic Information System (Arc Info) was used. Possible shoreline inundations are modeled using GIS Spatial and 3D analysis. (Figure 13) illustrates the findings. Based on the generated map areas to be inundated are calculated and are summarized in table 3.

Table (3): Inundated areas in 2100 due to sea level rise different scenarios.

Scenario	Trend in $cm.yr^{-1}$	Variation 2000-2100 in cm	Inundated area in km^2
Very low	0.6	60	17.56
Low risk	0.9	90	20.27
Moderate risk	1.3	130	23.89
Intermediate risk	1.9	1.9	27.57
High risk	2.5	250	30.35
Extreme risk	>5	500 up to 750	118.90

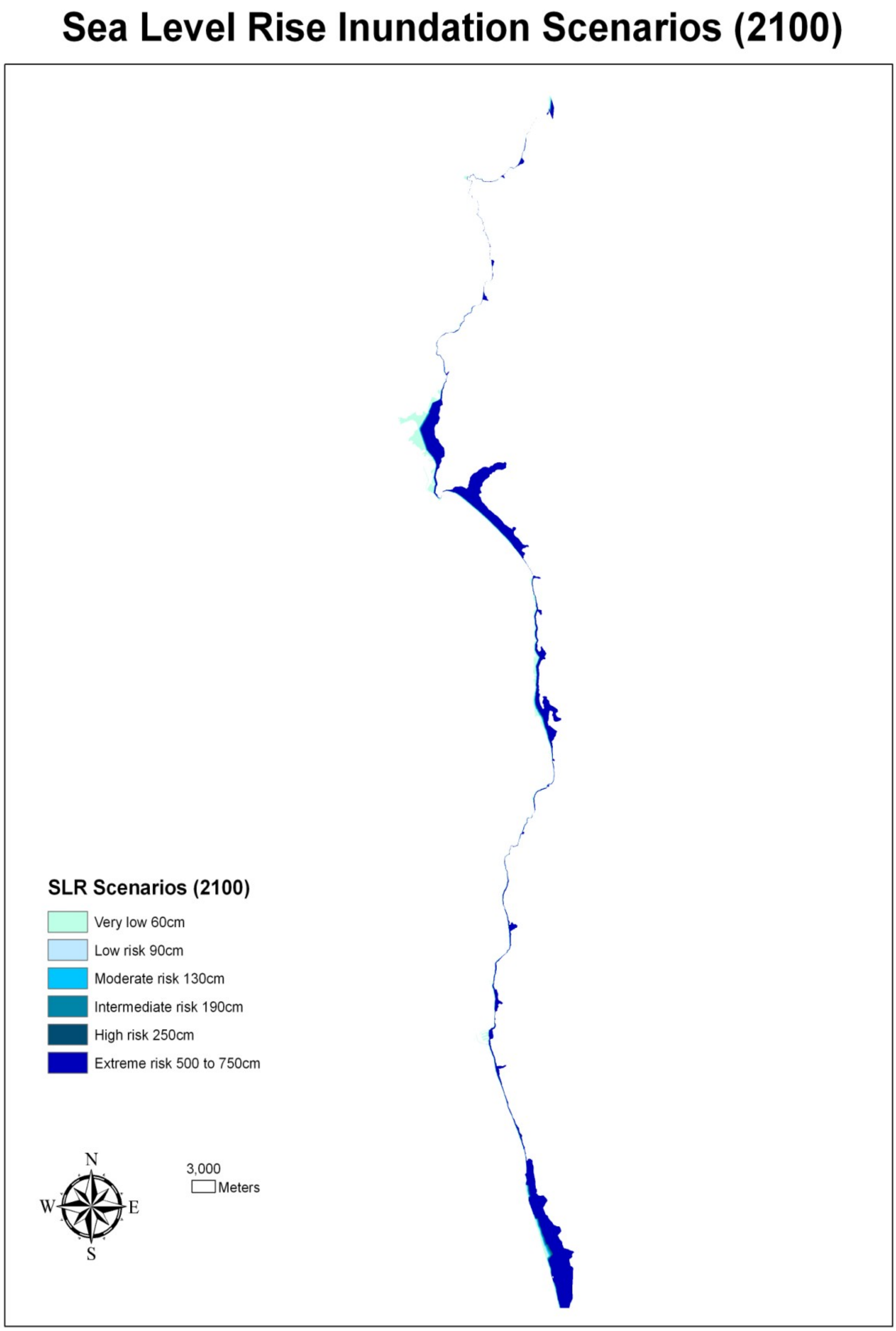

Figure (13): SLR inundation map, 2100

7. Assessment of Coastal Vulnerability Index

The prediction of coastal vulnerability is not straightforward. There is no standard methodology, and even the kinds of data required to make such predictions are the subject of much scientific debate. In order to develop a rational assessment of coastal vulnerability, relevant information is required. The compilation of this database is integral to mapping potential coastal changes due to sea-level rise. This database follows an earlier database developed by (*Gornitz et al*., 1997)[38]. A comparable assessment of the sensitivity of the coast vulnerability to sea-level rise is presented by (*Shaw et al*., 1998)[39]. The input six physical variables their attribute are found in Table 4 ; they cover:

- geomorphology,
- coastal slope (percent),
- rate of relative sea-level rise (mm/yr),
- shoreline erosion and accretion rates (m/yr),
- mean tidal range (m) and
- mean wave height (m).

Table (4): CVI rankings.

Ranking of CVI Index					
	Very Low	**Low**	**Moderate**	**High**	**Very High**
Variable	**1**	**2**	**3**	**4**	**5**
Geomorphology Class	23, 24	22	21	12, 13, 40	11, 30, 50
Coastal Slope (%)	> 2	1.5 -2	1 - 1.5	0.5 - 1	< 0.5
SLR Change ($mm.yr^{-1}$)	< -1.2	-1.2 - 0.1	0.1 - 1.2	1.2 - 1.4	> 1.4
Shoreline erosion/ accretion (m)	> 2	1 - 2	1 - -1	-1 - -2	< -2
Mean Tide (m)	> 6	4 -6	2 - 4	2 -1	< 1
wave ranges (m)	< 1	1- 2	2 - 2.25	2.25 - 2.5	> 2.5

As described above, each variable is assigned a relative risk value based on the potential magnitude of its contribution to physical changes on the coast as sea-level rises. Table (4) shows the six physical variables as described in Risk Variables[40], ranked on a linear scale from 1-5 in order of increasing vulnerability due to sea-level rise. In other words, a value of 1 represents the lowest risk and 5 represent the highest risk. The database includes both quantitative and qualitative information. Thus, numerical variables are assigned a risk ranking based on data value ranges, whereas the non-numerical geomorphology variable is ranked according to the relative resistance of a given landform to erosion.

The coastal vulnerability index (CVI) is similar to that used by (*Gornitz et al*., 1994)[41], as well as to the sensitivity index employed by (Shaw et al., 1998). The index allows the six physical variables to be related in a quantifiable manner that expresses the relative

38 Gornitz, V. M., Beaty, T.W., and R.C. Daniels, 1997, A coastal hazards database for the U.S. West Coast. ORNL/CDIAC-81, NDP-043C: Oak Ridge National Laboratory, Oak Ridge, Tennessee.

39 Shaw, J., Taylor, R.B., Forbes, D.L., Ruz, M.H., and Solomon, S., 1998, Sensitivity of the Canadian Coast to Sea-Level Rise:Geological Survey of Canada Bulletin 505, 114 p.

40 http://pubs.usgs.gov/of/2000/of00-178/pages/risk.html

41 Gornitz, V. M., Daniels, R. C., White, T. W., and Birdwell, K. R., 1994, The development of a coastal risk assessment database: Vulnerability to sea-level rise in the U.S. southeast: Journal of Coastal. Research, Special Issue No. 12, p. 327-338.

vulnerability of the coast to physical changes due to sea-level rise. This method yields numerical data that cannot be equated directly with particular physical effects. It does, however, highlight those regions where the various effects of sea-level rise might be the greatest. Once each section of coastline is assigned a risk value for each specific data variable, the CVI is calculated as the square root of the geometric mean of these values, or the square root of the product of the ranked variables divided by the total number of variables as:

$$\text{CVI} = \sqrt{a \times b \times c \times d \times e \times f / 6}$$

Where: *a = geomorphology; b = coastal slope; c = relative sea-level rise rate; d = shoreline erosion/accretion rate; e = mean tide range; and f = mean wave height.*

The calculated CVI values range from 3.87 to 19.36; Mean is 14.10; and Standard Deviation equals to 3.78. (Figure 14) shows the coastal vulnerability index for the Syrian Coast. The CVI are divided into 5 categories from Very low to Very high risks based on the equal interval ranges. CVI statistics are summarized in Table 5.

Table (5): Statistics Based on Coastal Vulnerability Index

CV1		
Class	**Length in meter (m)**	**% of Total Length**
1	2741	1.5
2	40307	22.0
3	74722	40.8
4	29479	16.1
5	35751	19.5
Total	183000	100.0

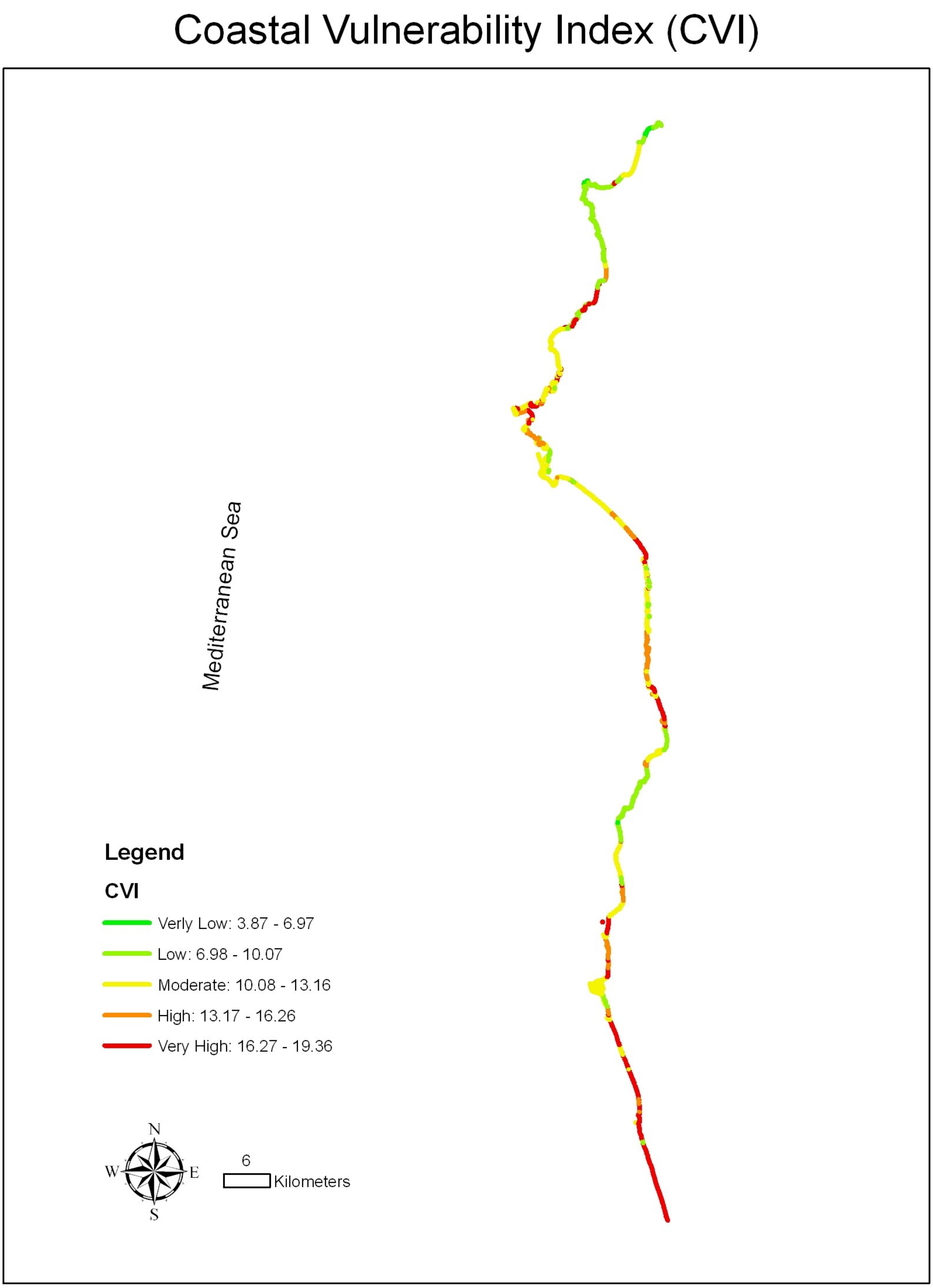

Figure (14):. Coastal Vulnerability Index (CVI)

8. Impacts and Discussions

Quantification of the socio-economic impacts based on the projected potential physical consequences that rising sea levels may induce is the topic of this section of the report. Impacts of sea-level rise on coastal lowland are usually the most to be considered. Low land's area is mainly vulnerable to an increase in the frequency of coastal inundation. Effects on estuarine backwater effects and sea water intrusion are another impact to be included. The human dimension mainly lives and livelihoods aspects are also discussed. Impacts on agricultural management are the final aspect to be included in this study. Overviews of each of the previous impacts in addition to the projected numbers are discussed below. However, it is rational to summarize the areas that are most vulnerable.

8.1. Degree of Vulnerability

Vulnerability refers to areas vulnerable due to the forecasted sea level rise. The criteria contributed in defining degree of vulnerability are: SLR, CVI, geomorphology, land use/ cover, and population. Based on these criteria coastal vulnerable areas are described below:

Most vulnerable coastal areas are:

- Flat and low-lying coastal plain (sandy and rocky within 0-1 m above MSL).
- Deltaic and estuaries coastal plain areas
- Sandy shores characterized by gentle slopping beach face.

8.2. Land losses and population displacement due to inundation

The most significant changes would occur where there is low-lying land. Natural covers and population – a growth rate of 2.5 was included in the estimation of population count by year 2100 – were overlaid using a GIS with the most optimistic (60cm) and pessimistic (5m) scenarios results. Results for the minimum inundation level (60cm) and for the high inundation level are summarized in tables (6 &7) respectively.

Table (6): Impact of SLR on Land use/ Cover.

Scenario	Very low risk: 0.6m	Extreme risk: 5-7.5m
Land cover	**Area in (sq Km)**	**Area in (sq Km)**
citrus plantations	0.69	11.50
citrus plantations and field crops	2.31	24.92
citrus plantations and olives	0.14	1.09
closed forest	0.00	0.23
closed *maki*	0.09	0.14
greenhouses and field crops	2.05	33.63
olives	0.04	0.41
olives and field crops	0.02	0.11
olives and greenhouses	0.13	0.46
open forest	0.00	0.01
open forest & shrubs	0.31	1.80
open *maki*	0.01	0.03
open *maki* and olives	0.00	1.05
sandy soil	0.99	7.98
urban areas	5.12	16.73

Table (7): Impact of SLR on population.

Scenario		Extreme risk: 5-7.5m
Coastal Population		Population at risk
1994	1.300.000	50.000
2100	3.250.000	125.000

8.3. Socio-economic impacts

Socio-economic impacts are characterized by the economical costs due to the increase in the flood risk and the impacts from inundation. Beaches will decline or be lost. Integrated coastal zone management and appropriate planning, including avoiding development in the flood plain are major reducer of the flood risk. Socio-economic impacts shall require a standalone study. A proposed framework[42] for assessing coastal system vulnerability is shown in (Figure 16). With management option depends more on socio-economic and political factors than on physical factors. The framework makes distinction between natural and socio-economic vulnerabilities. This vulnerability assessment shall provide important concept in the management of the effects of different sea level rise scenarios. There are four principal management existing options to deal with: (i) do nothing; (ii) managed retreat; (iii) accommodation; and (iv) protection.

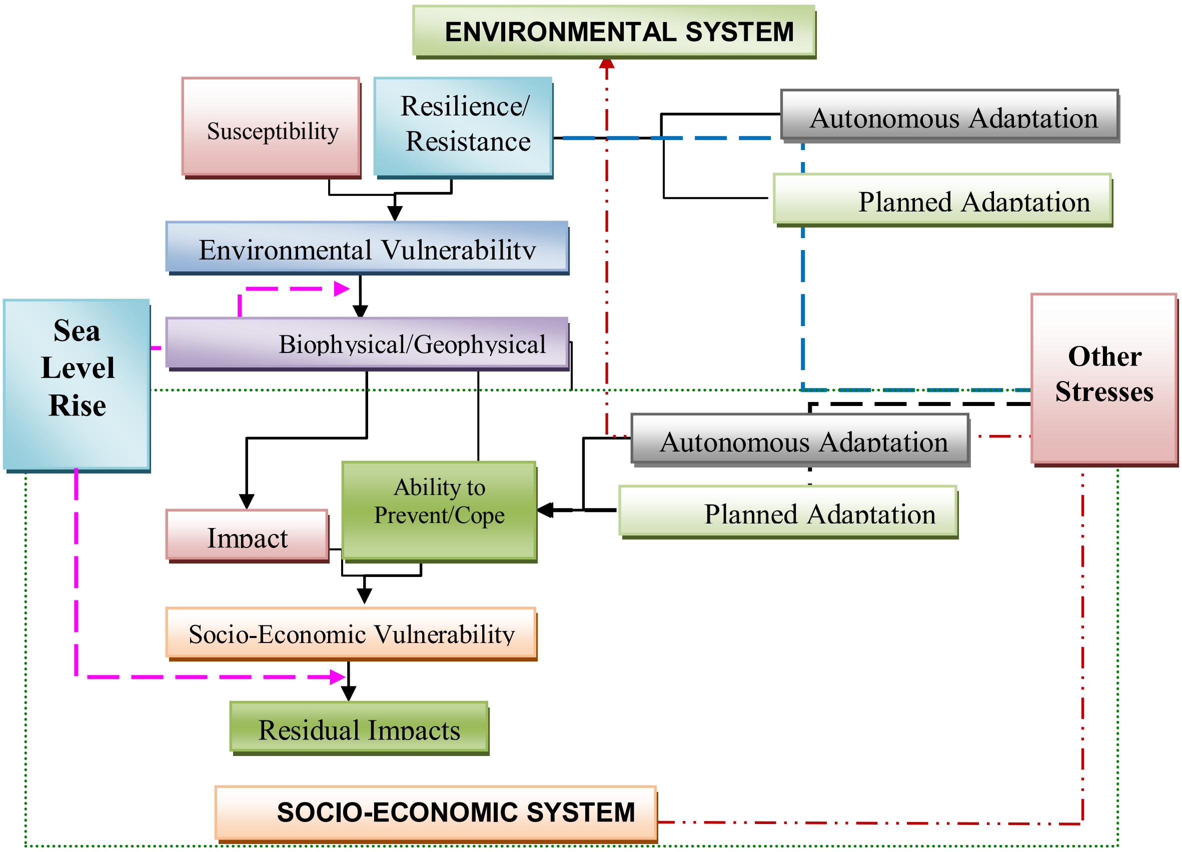

Figure (16): Coastal socio-economic and environmental vulnerability assessment.

[42] Klein, R.J.T and Nicholls, R.J., 1999. Assessment of coastal vulnerability to climate change. Ambio, 28, 182-187.

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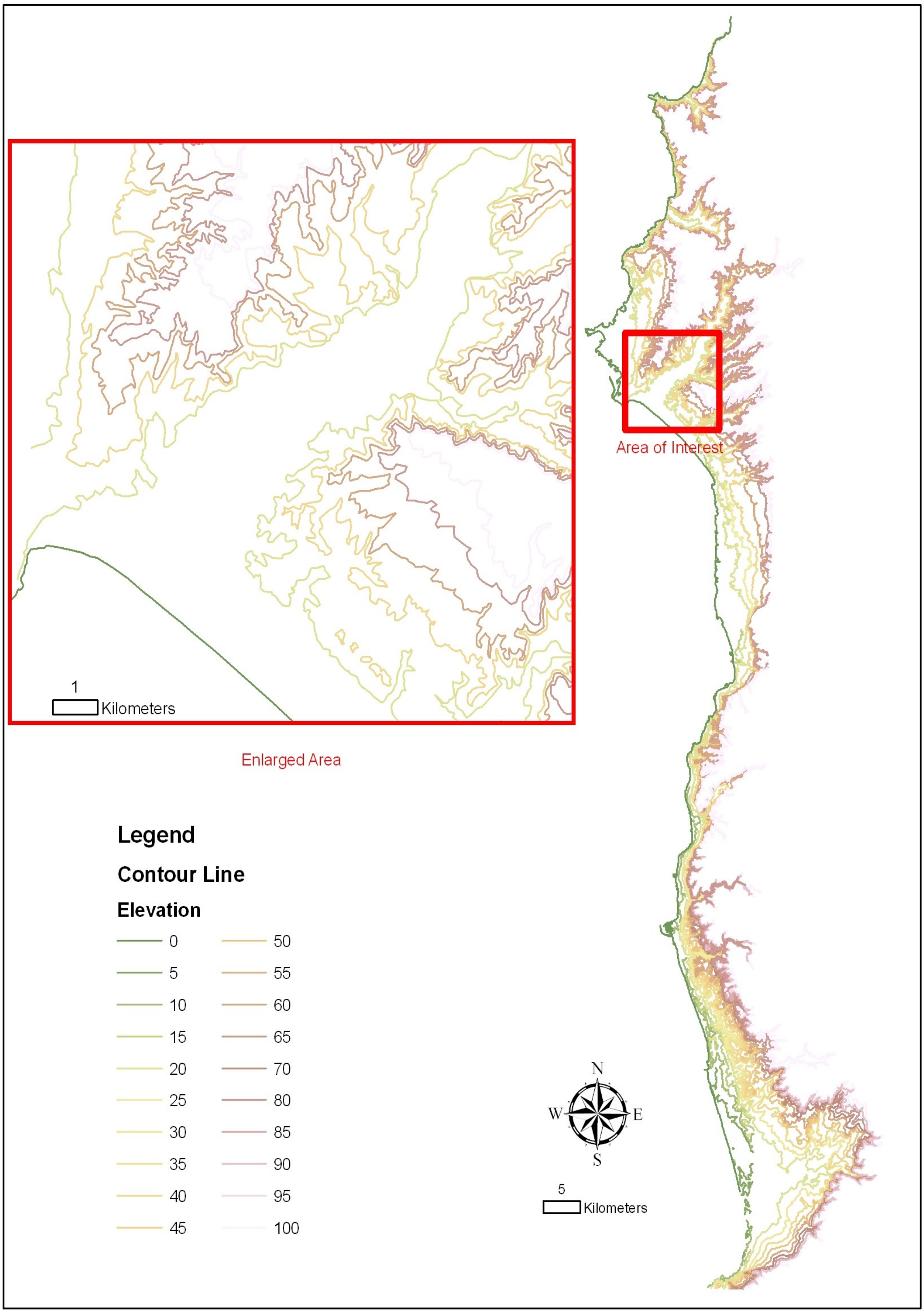
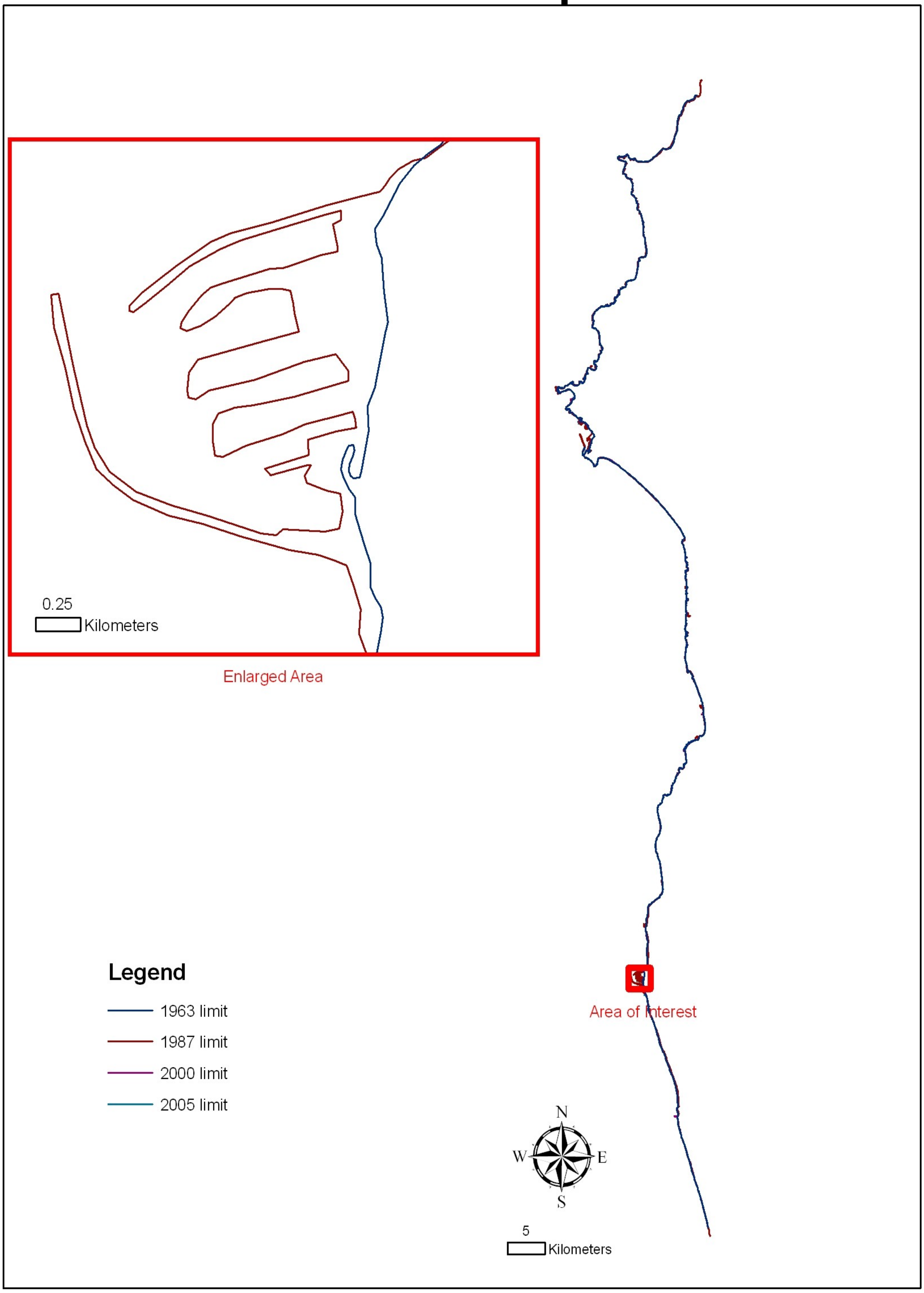
Appendix (1)

Map data

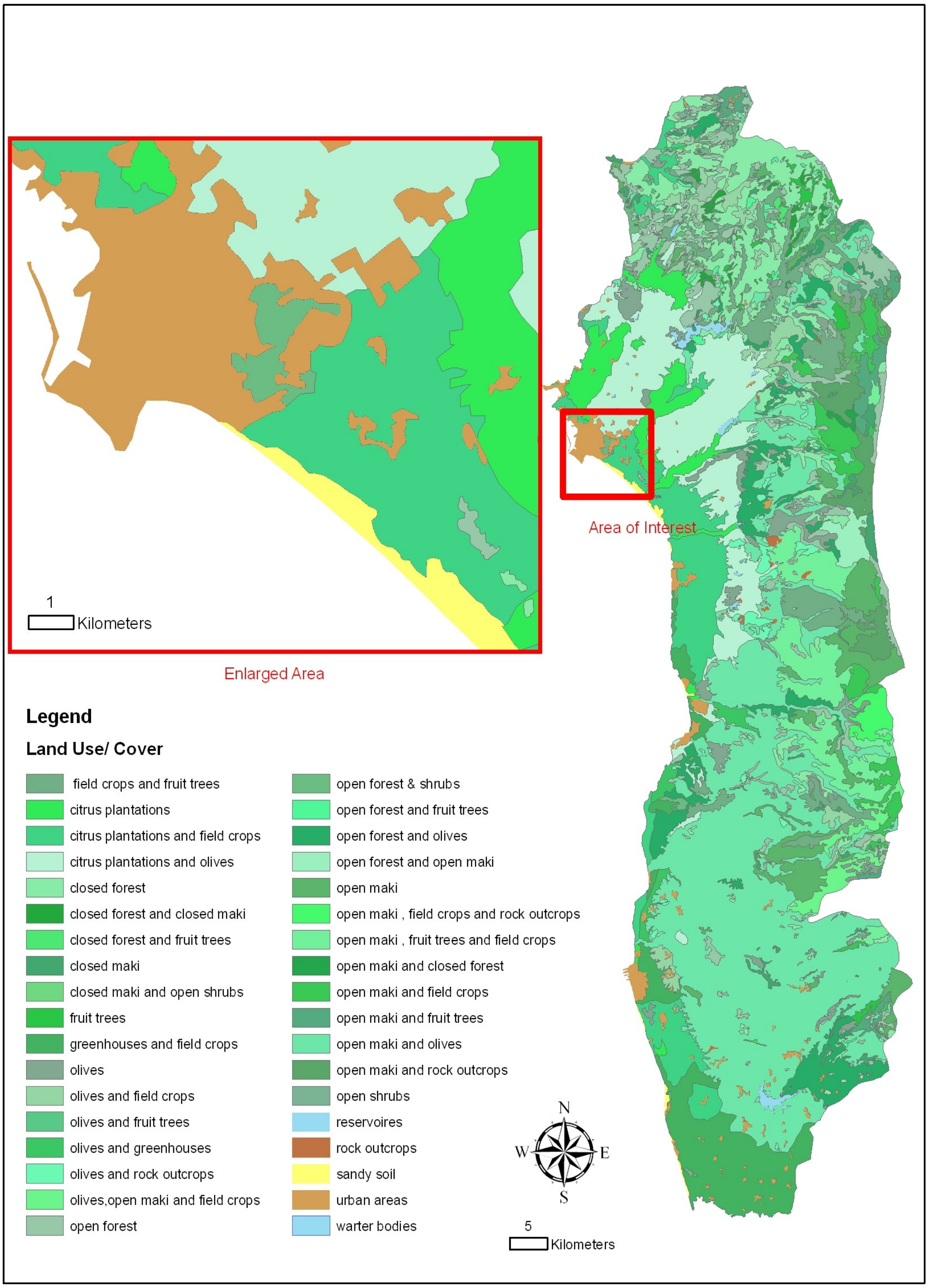
Contour Lines



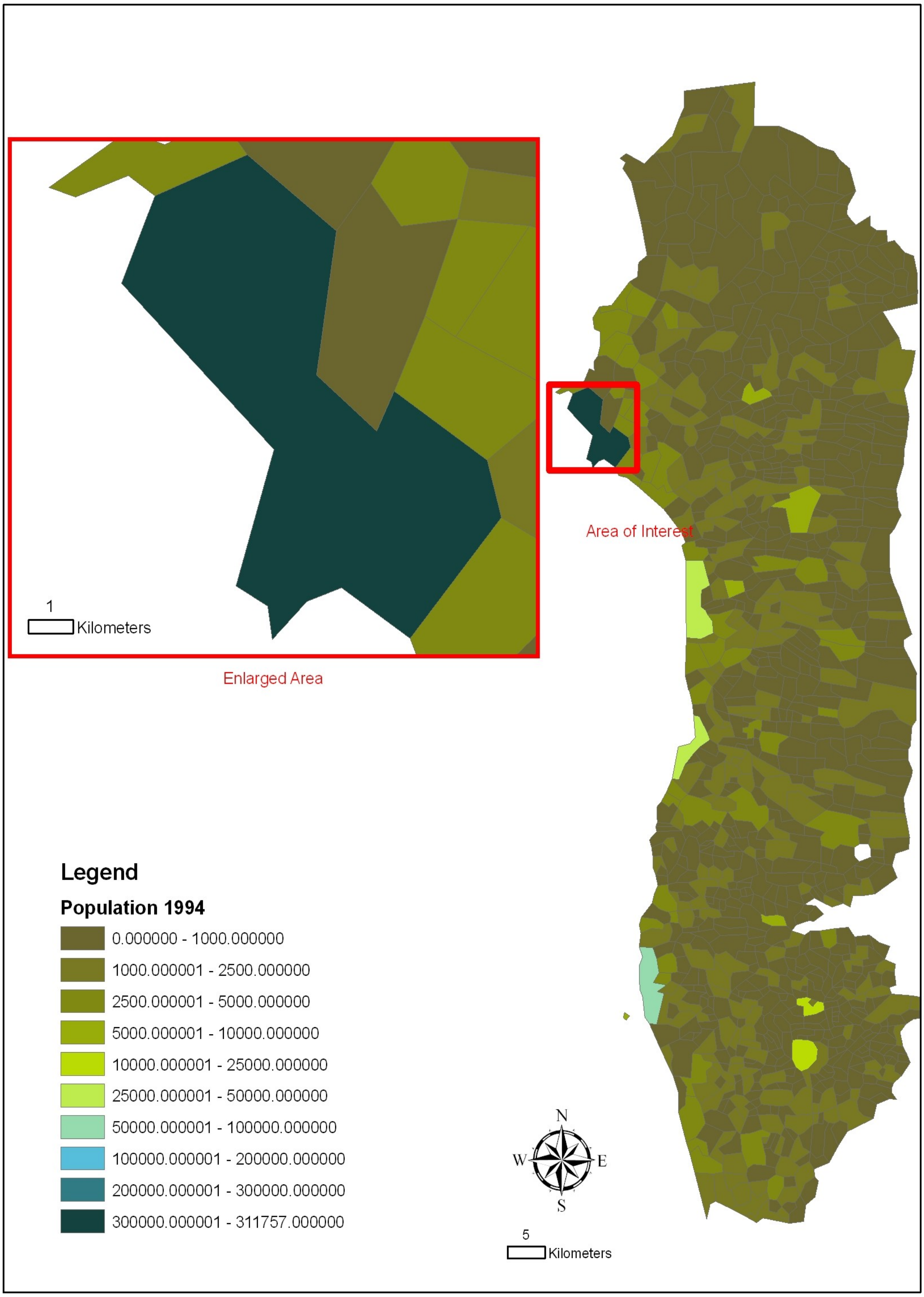
Shoreline development



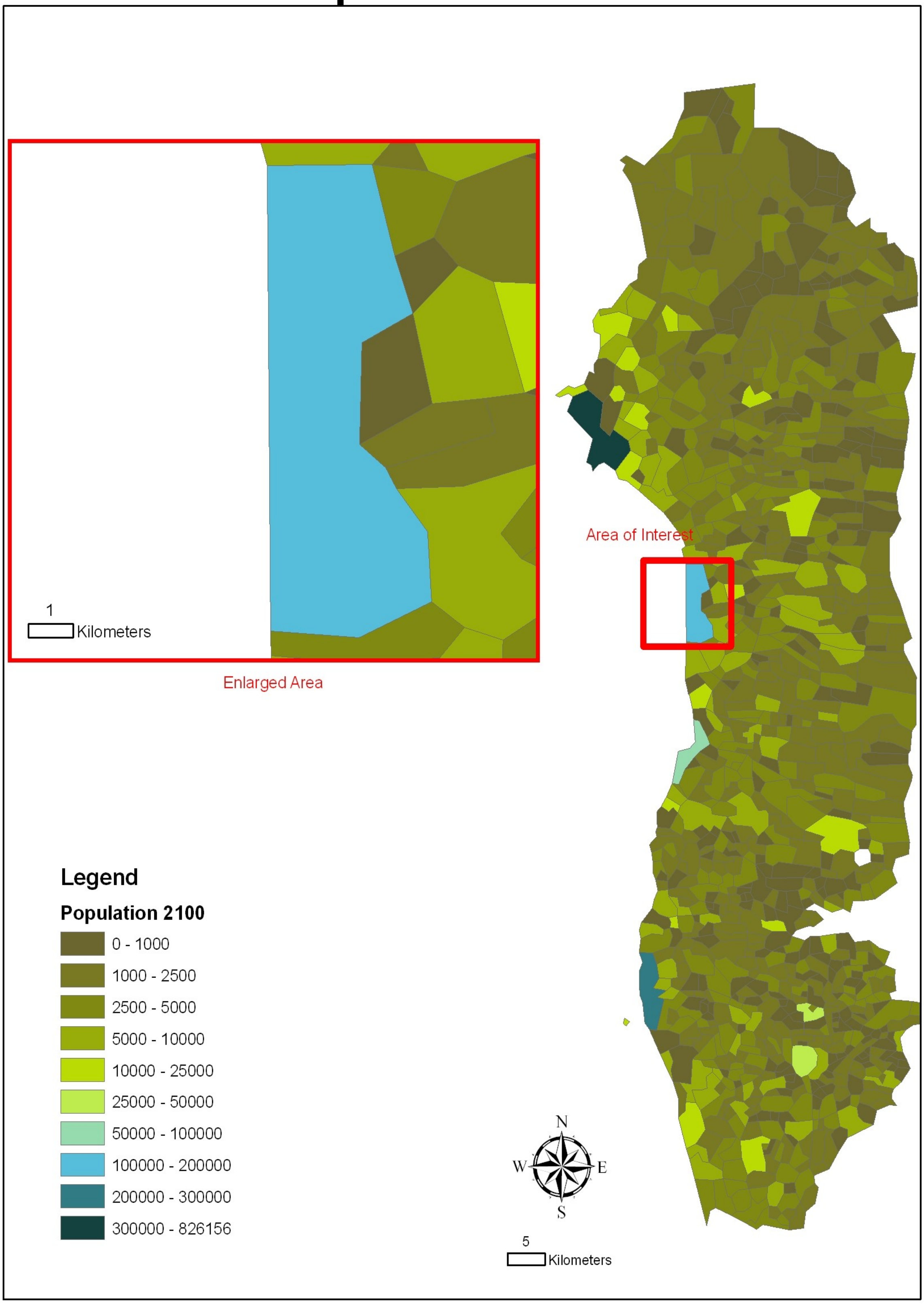
Land Use/ Cover



Land Use/ Cover



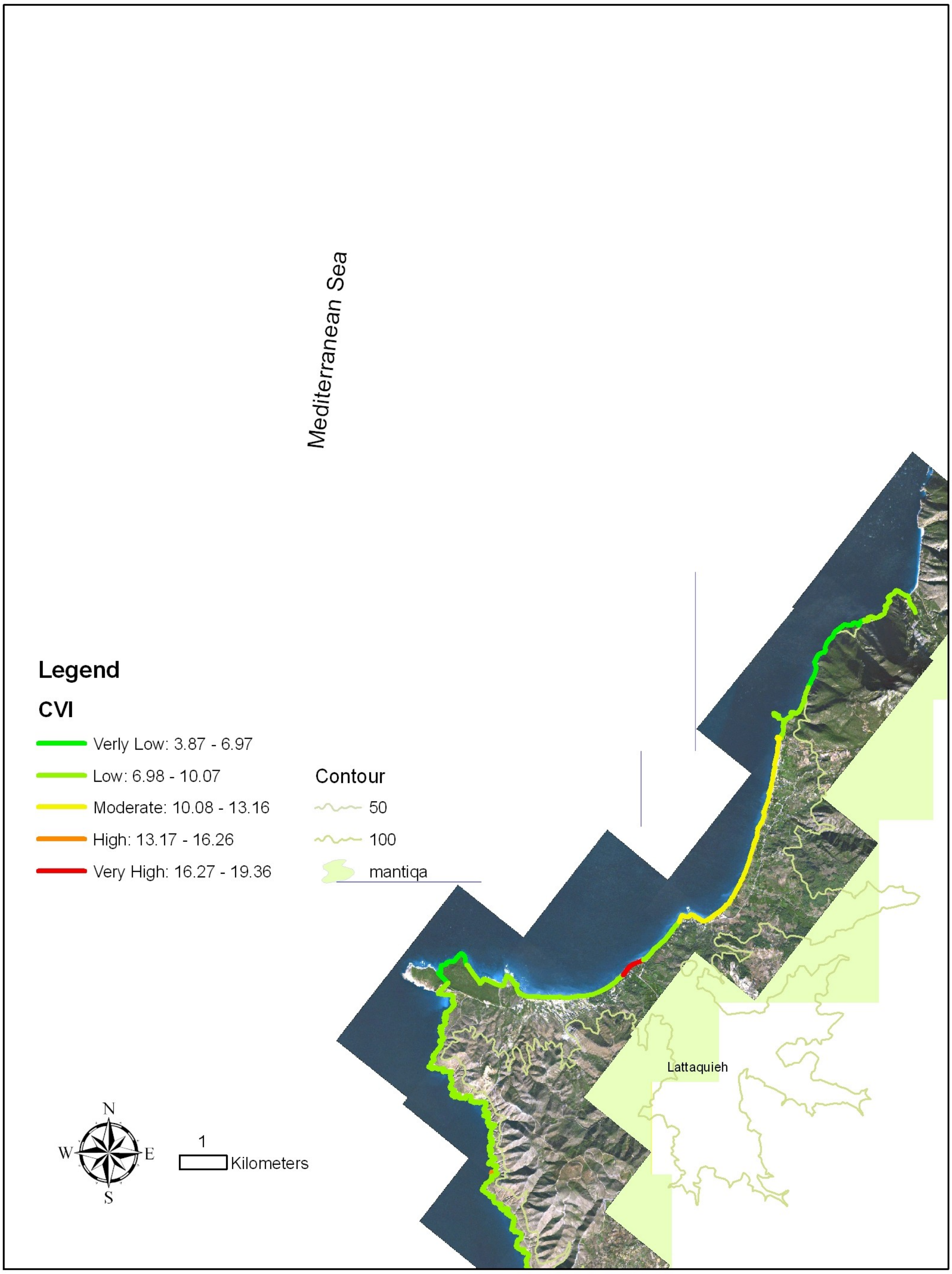
Population 2100



Appendix (2)

Coastal Vulnerability Index
Maps 1:100000

Coastal Vulnerability Index (CVI)



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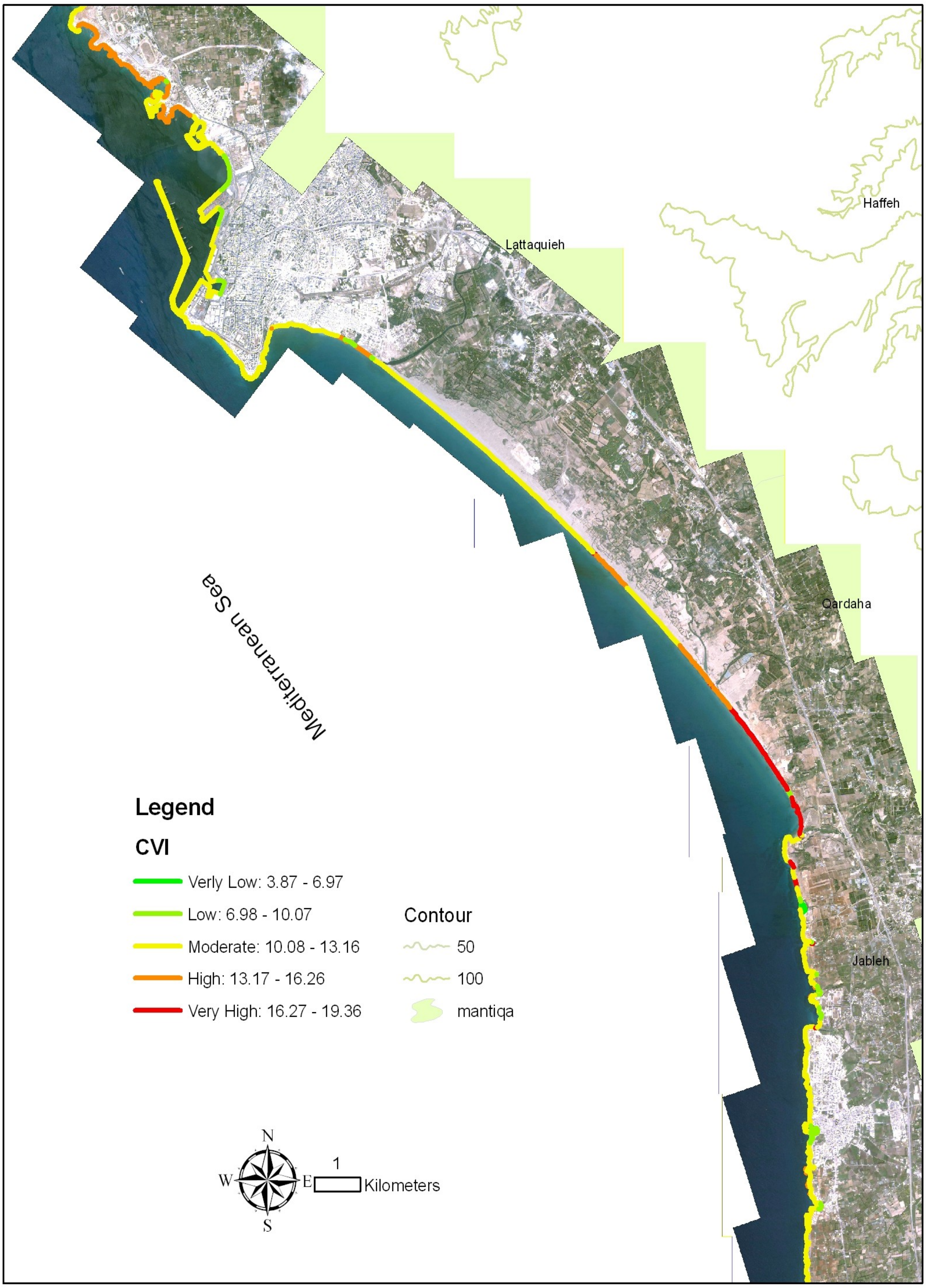

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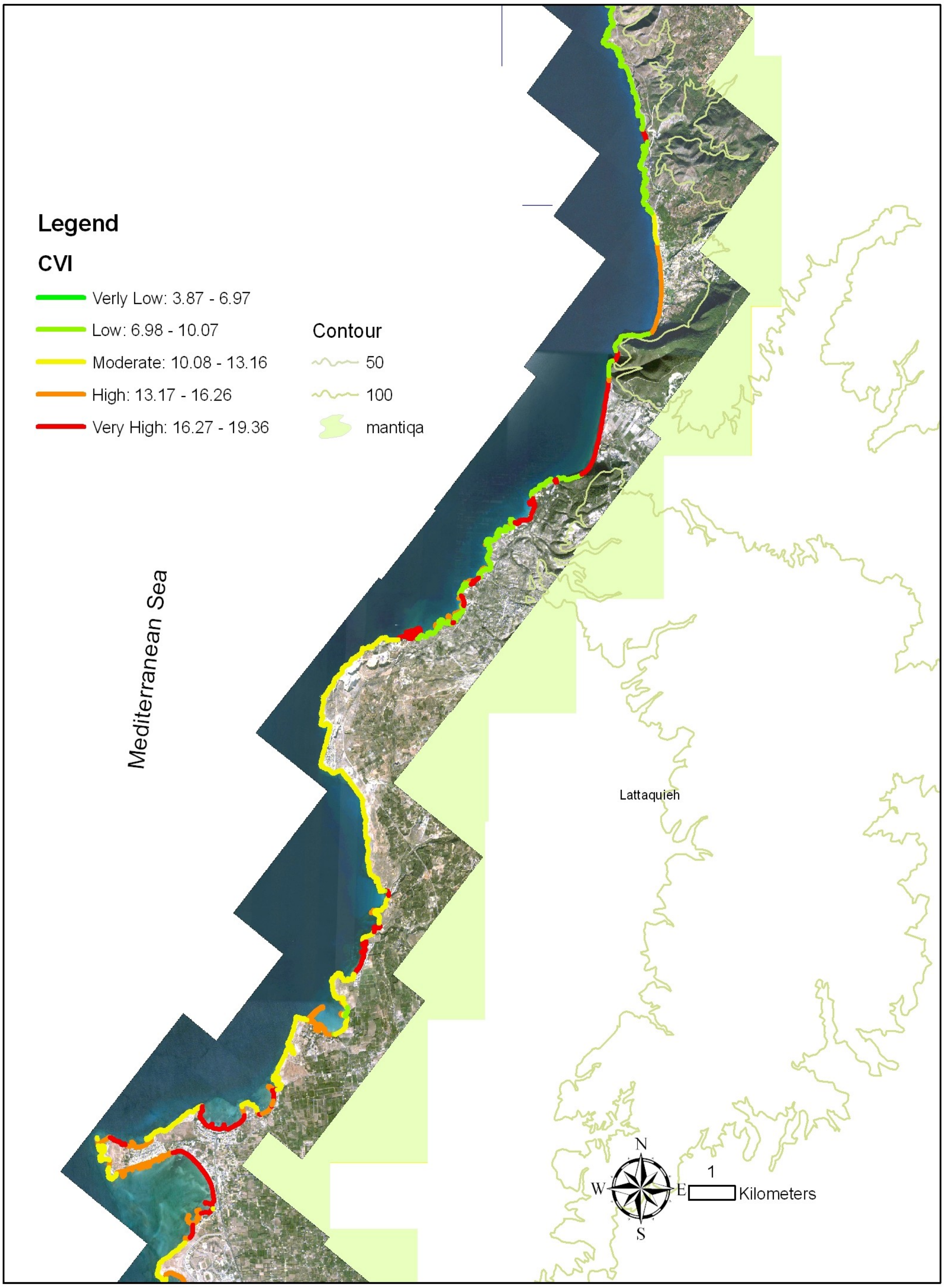

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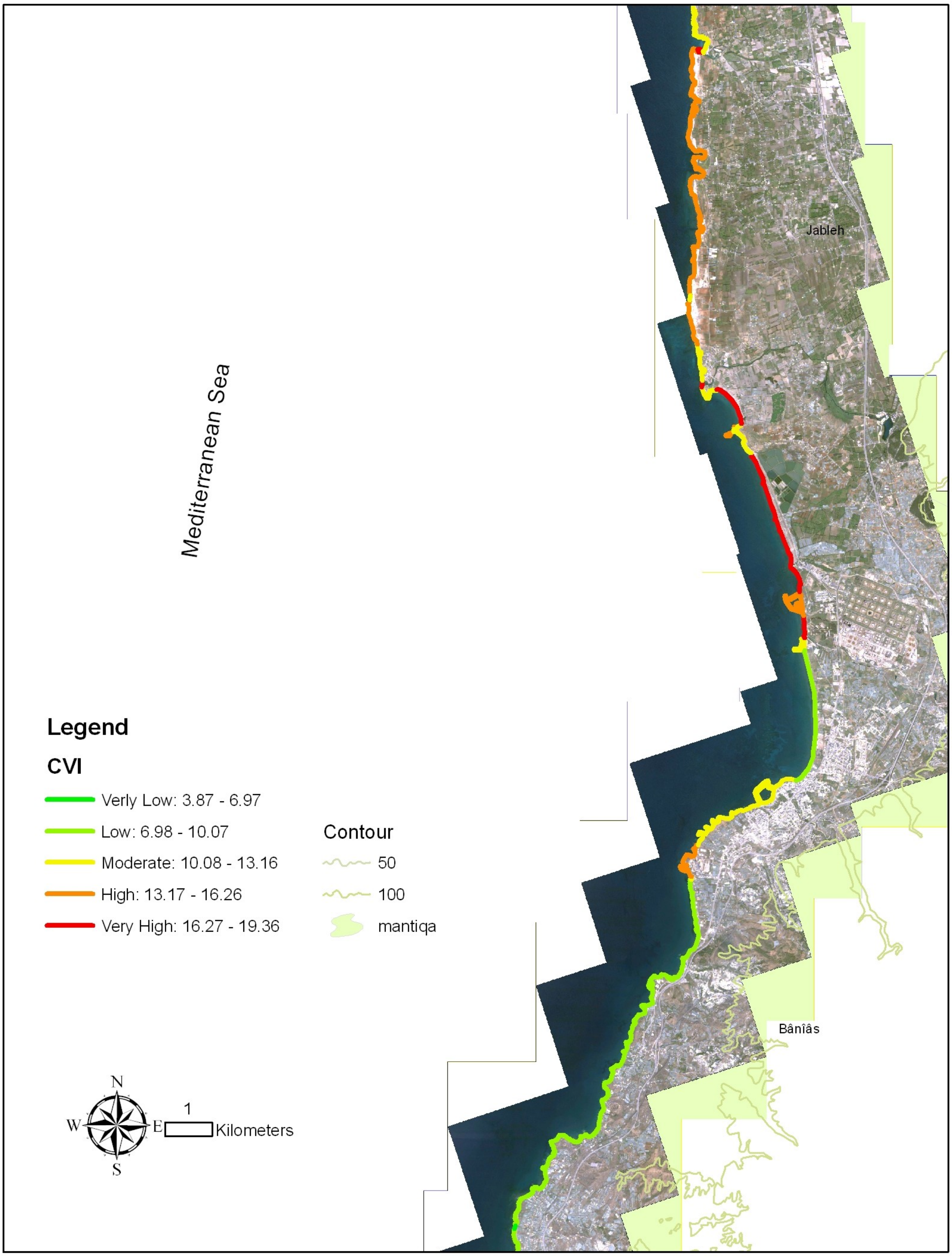
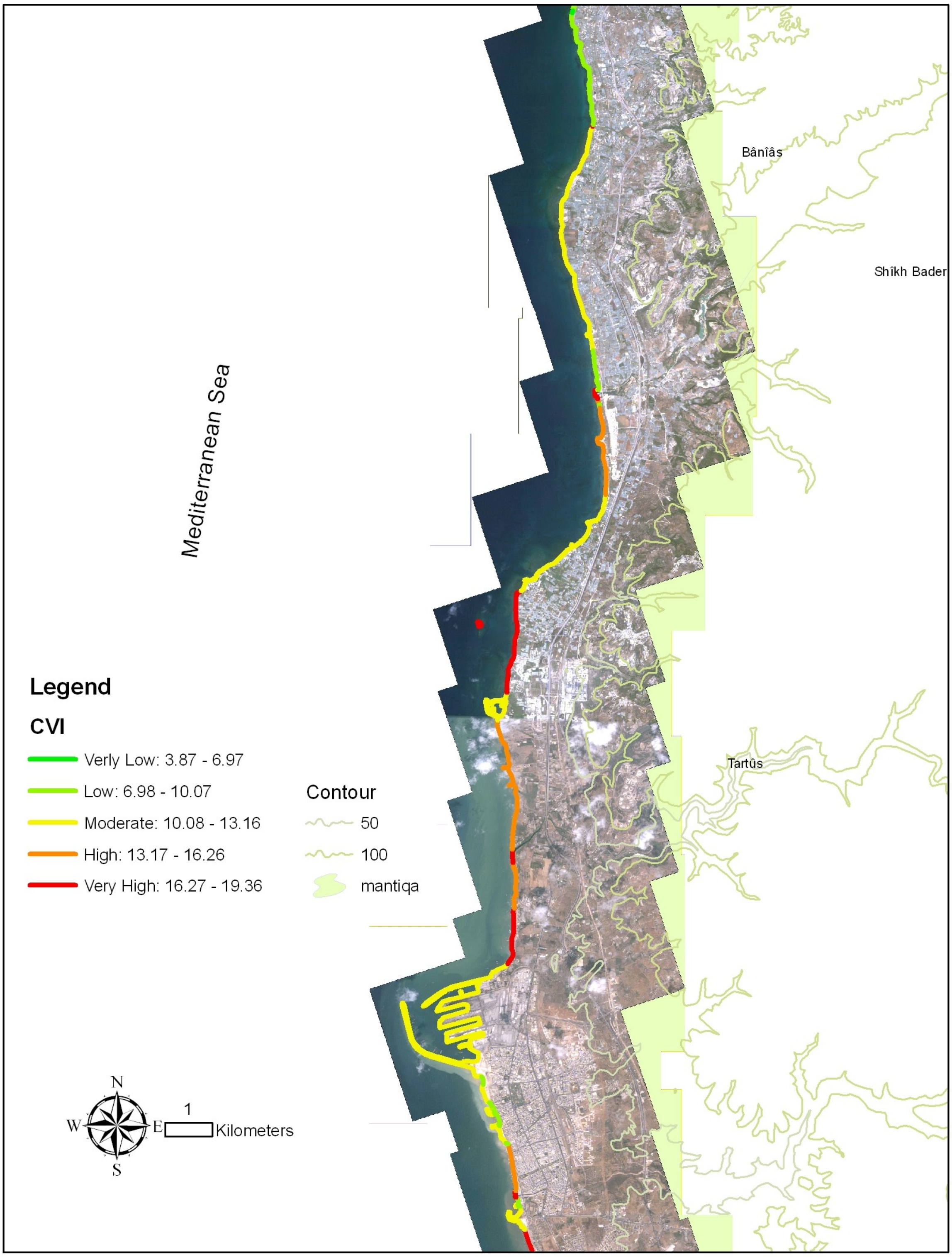


Coastal Vulnerability Index (CVI)



Coastal Vulnerability Index (CVI)