The Use of SRTM in Assessing the Vulnerability to Predicted Sea Level Rise in Yanbu Industrial City, Saudi Arabia

by

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Introduction

- **Vulnerability** is a concept that is perceived in very different ways by scholars from different domains of knowledge, and even within the same domain. (Fussel, 2007).
- Natural Scientists and Engineers.
- IPCC defines vulnerability as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes"(McCarthy et al. 2001).
- Vulnerability factors
- ”physical factors, which describe the exposure
- ”economic factors, which describe the economic resources
- ”social factors, which describe non-economic factors
- ”environmental factors, which describe the state of the environment within a region” (United Nations, 2004).

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Sea Level Rise

Sea level rise (SLR) is the changes in the in the the level of the surface of the sea with respect to the land, taken to be the mean level between high and low tide, and used as a standard base for measuring heights and depths.

It therefore, poses one of the major environmental challenges and major concerns of today.

One of the challenges of climate change and sea level rise is the coastal erosion and inundation

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The causes of sea level rise

Sea level rise may be attributed to the following factors:

- the increase in water volume that results mainly from thermal expansion of the ocean,
- melting of mountain glaciers,
- an accelerated discharge of glacial ice from the ice sheets to the ocean,
- contributions from thawing of permafrost,
- sediment deposition, and
- the continuing adjustment of the ice sheets.
- geological uplift or subsidence processes occurring in ocean basins and on continents
- The impact and extent of sea level on the immediate coastal environment depend on the scenarios

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Scenarios of Sea Level Rise

- In order to study the impacts of climate change and SLR on societies, different climate modeling groups have developed scenarios of SLR given expected rise in temperature (Aleem and Aina, 2012).
- These scenarios can be modeled using geospatial techniques such as Digital Elevation Model to study, analyse, assess and predict the vulnerability of different scenarios of sea level rise on global and local communities.

Warrick et al , 1996; Li et al, 2009; Aleem and Aina, 2012)

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1.2 Digital Elevation Model (DEM)

- A Digital Elevation Model refers to a quantitative model of a part of the earth's surface in digital form (Burrough and McDonnell, 1998)
- DEMs can be divided into two viz.: Digital Terrain Models (DTM) and Digital Surface Models (DSM).
- There are several methods of generating DEM Ranging from traditional Land Surveying method to Satellite methods
- An example of Satellites global DEM available online is SRTM.

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Shuttle Radar Topographic Mission (SRTM),

- SRTM is a product of interferometry radar data collected by NASA and US National Geospatial-Intelligence Agency (NGA), which has been used by the Jet Propulsion Laboratory (JPL) to generate a near-global (80% of earth's land mass) DEM.

- DEMs from the SRTM are available at 3 spatial resolutions:

(a) 1 arc-second DEM (30-m resolution) which covers only the United States

(b) 3 arc-second DEM (90-m resolution) covers the entire world; and

(c) 30 arc-second (1-km resolution) covers the entire world.

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1.4.2 Comparing SRTM and other DEMs

- In the studies by Li et al. (2009), Dasgupta et al. (2009), Sande (2011) and Babu et al. (2012); GIS and DEM data (SRTM, ETOPO and GDEM) were used to assess the vulnerability of sea level rise and comparative analysis of the result were carried out.
- Studies such as Sande (2011) Aleem and Aina (2012)have found that SRTM is better than other methods in modeling risks and vulnerability associated with SLR.
- Forkuor and Maathuis (2012), compared SRTM and ASTER GDEM with Referenced DEM. Their study has revealed that SRTM is "closer" to the Reference DEM than ASTER.
- in this work, SRTM has beed has been adopted.

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1.3 Aim and objectives

The main **aim** of this study study is to use DEM from SRTM data for assessing vulnerability to coastal flooding and inundation due to predicted sea level rise

The **objectives** of this study are:

- to obtain scenarios of global sea level rise from literature.
- to assess the vulnerability of Yanbu Industrial City to coastal flooding and inundation using the scenarios.
- to assess the impact of inundation on land use and population

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1.4 Study area

The study was carried out in Yanbu Industrial City, popularly known as Yanbu Al-Sina'iya in Arabic, which literarily means Industrial Yanbu in Madina Province of Saudi Arabia (Figure 1). The city, established around 1975, is located on the Coast of Red Sea about 350km North of Jeddah, one of the major ports in the Kingdom. The city is located on: Latitude 23^0 59' 57.840"N (23.9994) and longitude $38^0$13' 39.000"E (38.2275). (Fig. 1).

Yanbu a petroleum shipping terminal, home to 3 oil refineries, a plastic factory and several other petrochemical plants.
Yanbu Industrial City can be regarded as a Low Elevation Coastal Zone (LECZ), according to Mcgranahan (2007).
Unlike, other coastal cities, the population of Yanbu is moderate because of the control measures by RC

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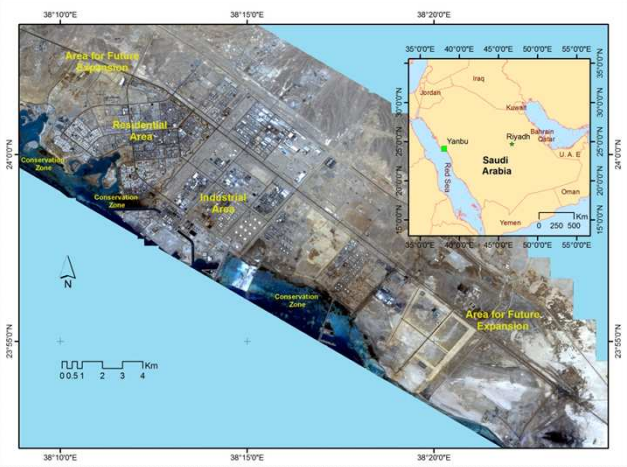

Figure 1: Map and Land use Pattern of Yanbu Industrial City

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Population and Land Use of Yanbu Industrial City

Population of Yanbu Industrial city is 91479 based on 2010 Kingdom of Saudi Arabia Census.

Land use of Yanbu Industrial City comprises of 4,240 hectares for community and residential area, the water front covers about 381 hectares and buffer / open space is about 2100 hectares of land. This work aimed at studying the effect of sea level rise on the land use pattern of Yanbu Industrial City using the freely available online DEM from SRTM

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2.0 Materials and Methods

- DEM data of the SRTM (global land cover facility) were downloaded from the Consortium for Spatial Information (CSI) web portal (http://srtm.csi.cgiar.org/)
- changing the projection to Universal Traverse Mercator (UTM- Zone 37) and cell size to 90m) using ARCGIS software (Figure 2).
- Generally, studies of inundation due to sea level rise adopt a minimum scenario of 1m SLR, but Sande et al. (2012), have included storm surge in their sea level rise analyses. Also, the RMSE of SRTM DEM compared with LiDAR or GPS data have been found to be around 2m to 5m (Sun et al, 2003; Tachikawa et al, 2011; Sande et al, 2012 and Schumann et al, 2007). Thus, this study adopted scenarios of 1m, 2m, 3m and 5m, to cover the expected SLR of 1m, storm surge and the difference between SRTM and GPS or LiDAR data.

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2.0 Materials and Methods Contd.

- The results of the extracted areas were overlaid on land use and demographic data to compute the effect of inundation on land use and population.
- The population data for 2012 was estimated from the SEDAC data based on 5% annual population growth as stated in the 2012 economic plan and report of Yanbu Industrial City (RCJY, 2012).

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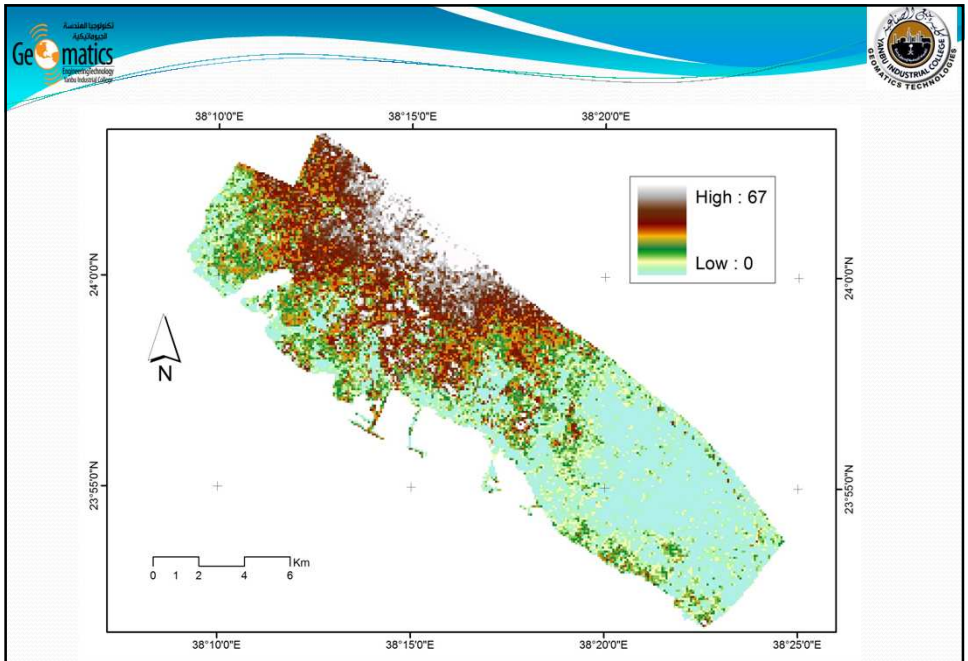

Figure 2: The SRTM DEM of Yanbu Industrial city

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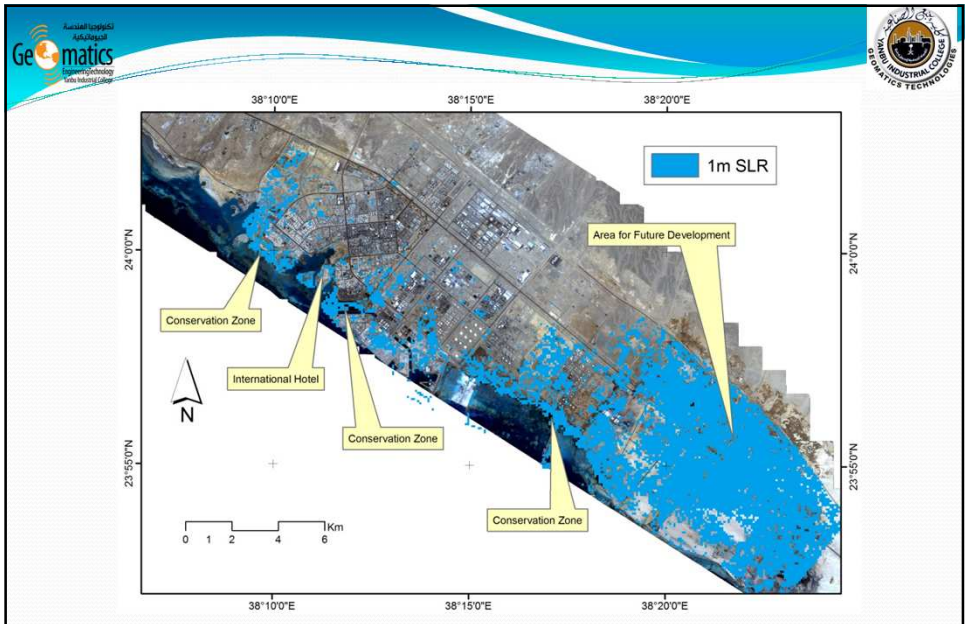

Figure 3: Area Affected by 1m Sea level Rise in Yanbu Industrial Ci

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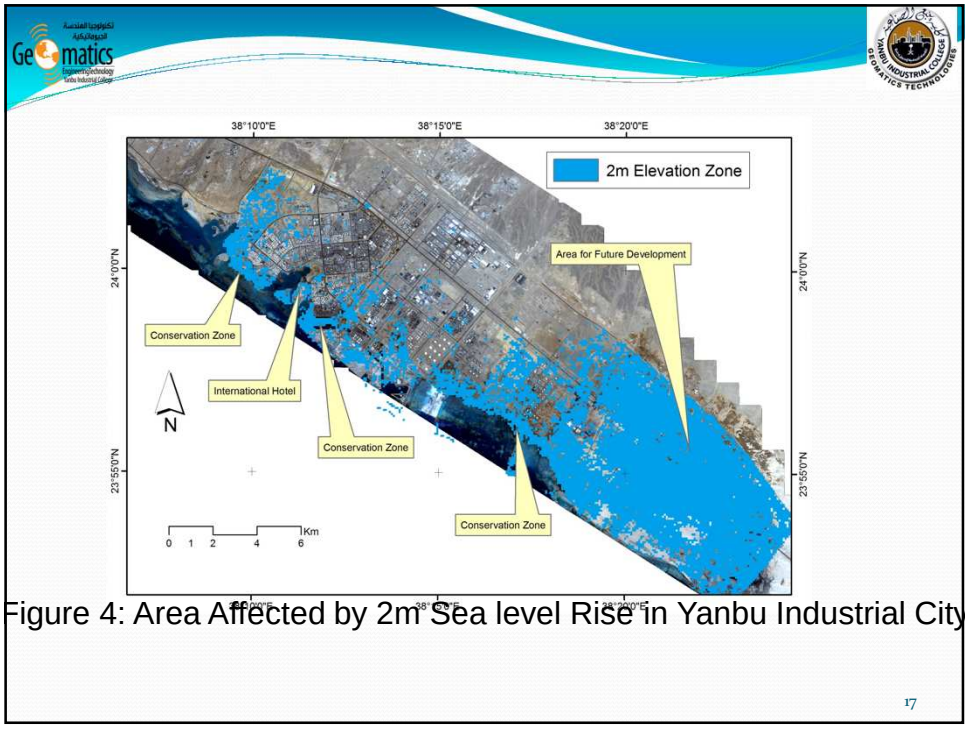

Figure 4: Area Affected by 2m Sea level Rise in Yanbu Industrial City

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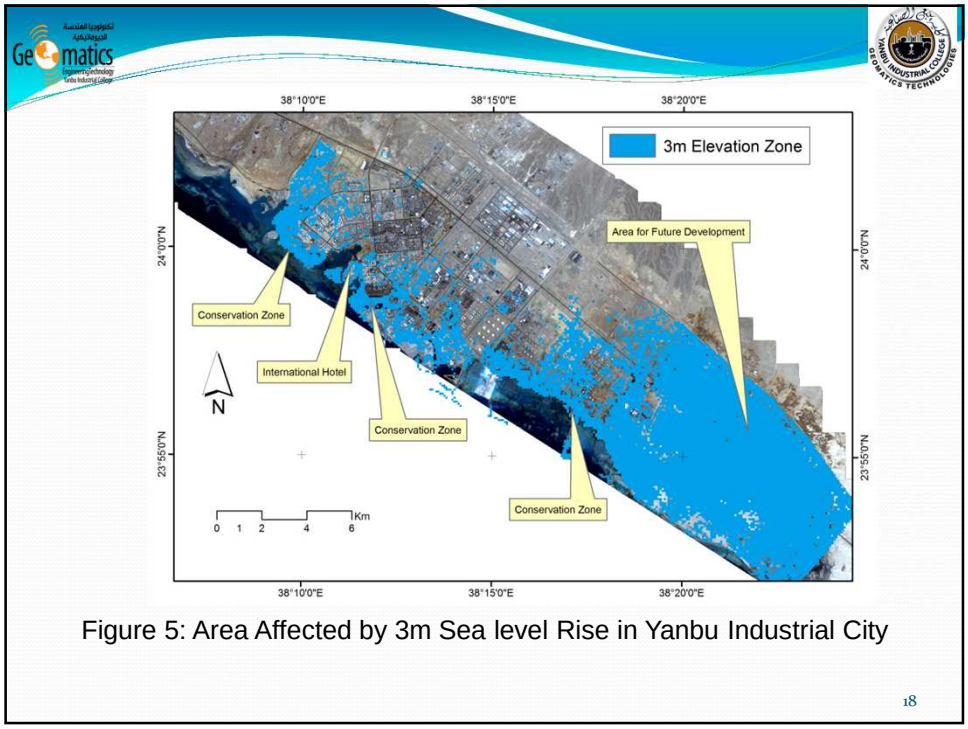

Figure 5: Area Affected by 3m Sea level Rise in Yanbu Industrial City

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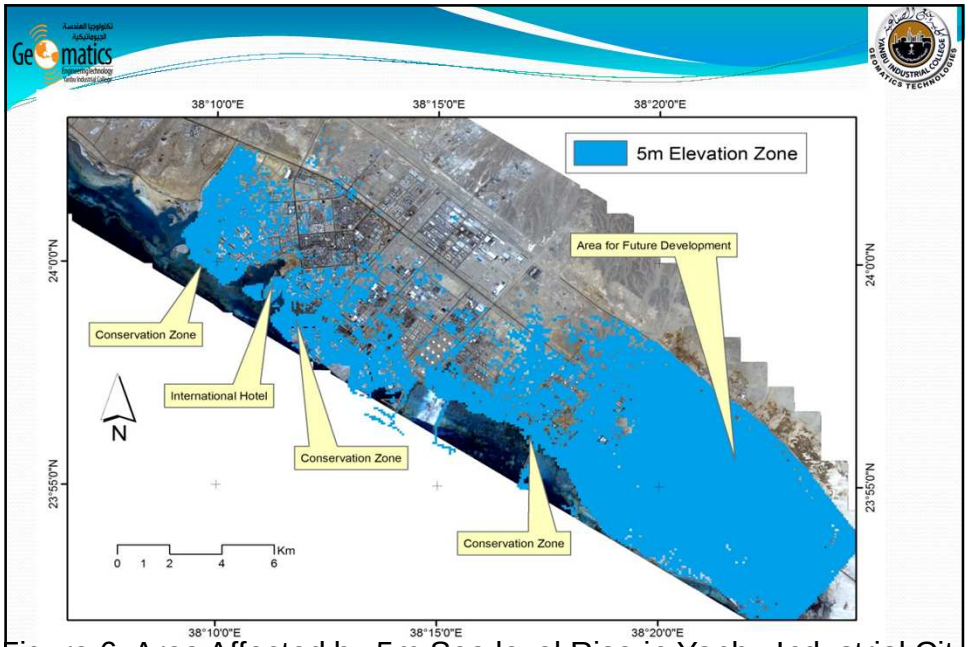

Figure 6: Area Affected by 5m Sea level Rise in Yanbu Industrial City

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Table 1: Estimates of Affected Land Use Patterns by different Scenarios of SLR.

Scenarios of SLR	Residential	Industrial	Area For Future Development	Total Area
1	50.706	271.188	421.524	743.418
2	72.819	341.091	482.193	896.103
3	99.63	397.872	518.805	1016.31
5	158.598	504.468	558.09	1221.16

Table 2: Estimates of Affected Population by different Scenarios of SLR.

Scenarios of SLR	Estimated Area to be affected	Year 2000 Population	Projected Population for 2012
1	743.418	17000	30530
2	896.103	18000	32325
3	1016.307	20000	35917
5	1221.156	22000	39500

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3.2. Discussions

According to the different scenarios the impacts of sea level rise were predicted for Yanbu Industrial City. A sea level rise of 1 m (Figure 3) could potentially flood a total area of 743.418 hectares, which represents all the land below 1m elevation. The whole areas for future area for expansion would be affected.

2m (Figure 4) could potentially flood a total area of 896.103 hectares.

3m (Figure 5) could potentially flood a total area of 1016.307 hectares.

5m (Figure 6) could potentially flood a total area of 1221.156 hectaress, which represents all the land below 5m elevation.

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3.2 Discussion Contd.

- The greatest impacts will be in the area designated for future development, which covers more than half of the areas to be affected by 1m to 3m inundation.
- For example an international hotel, all the three conservation zones, residential and industrial areas are at risk of 1m inundation.
- The conservation zones contain mangroves and coral reefs which are very important to the ecosystem, especially in a desert where such are very scarce to come by will be flooded.
- About 30530 people will be affected when the sea level rises by 1m and this figure can rise to about 39500 at a scenario of 5m. Most of these people are expatriates and high class Saudis

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4.0 Conclusion and Recommendations

- DEM data from SRTM was used in a GIS environment to analyse the vulnerability of coastal flooding and inundation due to sea level rise. Scenarios of sea level rise for 1m, 2m, 3m and 5m were used for the analyses. The study indicates that SRTM DEM data is suitable for depicting areas prone to inundation due to sea level rise in the study area.
- Considering the current rates of global sea level rise which is about 1.8 mm/year (Church et al. 2004), and 2.5 mm/year as indicated by Cazenave et al. (2008); the sea level should rise only between 0.18– 0.25 m by the end of this century (Hereher, 2010). This might not pose a major threat to Yanbu Industrial city but the predicted 1m rise by the year 2100 is a major challenge, especially now that the IPCC scenarios are being reviewed to take into consideration recent melting of Polar ice and other factors.

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Recommendations

The author recommends as follows:

- Coastal defences such as raised coastal sand dunes, coastal ridges and elevated coastal strips should be built along the coast to act as the first barrier that help protect inland areas, particularly existing low-laying lands, from inundation and sea surges.
- Since a rise in sea level by 1m will affect most of the areas for future expansion, we therefore recommend that sand filling and other prevetive measures should be carried out before the construction works are commenced.

Thank you for your attention

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