Journal of Applied Biological Sciences 7 (3): 56-60, 2013
ISSN: 1307-1130, E-ISSN: 2146-0108, www.nobel.gen.tr

Assessment of sea level rise impact on population and land use in the Mediterranean coast of Turkey

O. İnanç GÜNEY
Vocational School of Adana, University of Cukurova, Adana, Turkey

*Corresponding Author
E-mail: iguney@cu.edu.tr

Received: November 10, 2013
Accepted: December 26, 2013

Abstract

In this research, physical and socio-economical effects of sea-level rise were analyzed and simulated based on a series of land elevations for the years 2000 to 2100 respect to the Intergovernmental Panel on Climate Change. The study area, Cukurova delta coastal zone is located on the south-eastern Mediterranean coast of Turkey which lies 110 km long from east to west and represents an internationally important coastal ecosystem. In order to evaluate the land vulnerability due to sea level rise, digital elevation and geographical information system (GIS) data model, socio-economic data, natural neighbour interpolation algorithm and basic GIS methods were used. Model analyses showed us the area between 0 and 3 m contour line which is totally 101.399 ha coast lands will be lost under the accepted scenarios which comprise 35.430 ha wetlands, 32.393 ha agricultural land, 13.202 ha pasture, 4.351 ha sand dune, 3.368 ha salt marshes – swamp, 295 ha settlements river, road etc.

Keywords: Sea level rise; GIS; Turkey; socio-economic impact; land use

INTRODUCTION

Sea level is rising at an approximate rate of 2 mm/year [6] and is expected to accelerate over the next 100 years. The Intergovernmental Panel on Climate Change (IPCC) Second Assessment estimated global mean sea level rise from 1990 to 2100 to be in the range 23-96 cm [24]. The most recent IPCC estimation has reduced the expected global-mean rise to between 9 and 88 cm [7]. The new model projections of the IPCC scenarios give a global mean sea-level rise of 0.09 to 0.88 m by 2100, with sea level rising at rates approximately 2 to 4 times faster than those of the present day [15]. Sea level rise until this moment has also been significantly faster than predicted in the 2007 IPCC reports. In Europe, regional effects may result in sea-level rise being up to 50% more high than these global estimates [25]. The impact of the North Atlantic Oscillation on winter sea levels provides an additional uncertainty of 0.1 to 0.2 m to these estimates [21].The impacts of this rise have been provable such as beach erosion and loss of wetlands. Other such effects as higher sea water temperatures, changes in precipitation patterns and in storm tracks, frequency, and intensity, will also influence coastal systems, both directly and through interactions with sea level rise. On the other hand, impacts of sea level rise are important for the entire world’s socio-economic structure. It is estimated that 1.2 billion people, or approximately 23 % of the world’s population, live within 100 m of sea level and 100 km from a coast [18]. The population densities in coastal regions occur at approximately three times the global average with maximum densities occurring below 20 m in elevation [18]. Low-lying populated areas, such as residences built on deltas are most vulnerable to rising sea level.

The probability of a great rise in sea level has faced scientists with risk assessment for coastal area. During the 1990s, researchers in many nations began to assess the land that could be threatened by a rising sea [20]. Attempts to estimate inundation and shoreline change require data on land and water surface elevations, and a model of coastal processes [20]. Elevation maps, Digital Elevation Model (DEM), database and tabulations of the areas that the maps describe have been significant to assessing sea level rise and its risk [3-4-16]. These data are also important for coastal policy makers that estimate coastal land uses which can be left under the sea.

According to Karaca [13] there has been no specific assessment of potential impacts of the 50, 100 and 200 cm sea level rise scenario for Turkey although there are several reasonable introductory estimates. Geodesy Department of General Command of Mapping (GDGCM) is still monitoring sea level changes by means of Turkish National Sea Level Monitoring Network in Turkey. GDGCM has a data centre and eight survey stations. The location of these stations are as follows; two in the Mediterranean Sea, two in the Aegean Sea, one in Marmara Sea and three in the Black Sea.-Data acquired from these stations show that the sea level is raising in Turkish coastal zone (Table 1).

Based on the projections of sea level rise, this study assesses the global extent of potential inundation and its impact on land cover and population. The objectives of this research are: to determine areas at risk from flooding; to assess the most vulnerable land use at risk; to estimate the influence of coastal landscapes; and to identify the most plausible options available to mitigate these risks to the coastal zone.

Table 1. Mean sea level changes in Turkey

Station	Year	Sea Level Rise (mm/year)
Antalya II	1985-2002	8.7 ± 0.8
Bodrum II	1985-2002	3.3 ± 1.1
Mentes	1985-2002	6.8 ± 0.9
Erdek	1984-2002	9.6 ± 09

Study area

A rise in sea level would cause erosion and inundation, and also move the zones at risk of flooding upward and landward [19]. According to Behnen [2], areas below 10 m level are most vulnerable to sea level rise. Lower slopes experience a greater increase in flood risk due to sea level rise than steeper slopes [19].

The study area of the Cukurova delta coastal zone is located in south-eastern Mediterranean coast of Turkey (Figure 1).

It represents an internationally important coastal strip ecosystem, which is 110 km long. The coastal zone of Cukurova delta is one of the most important agricultural and industrial centres of Turkey as it makes important contributions to total agricultural crop production of the country and provides land for industries especially related with agriculture and energy. The most important cash crops grown in the delta are cereals (especially wheat and maize), fruits (especially citrus) and vegetables, soybean and cotton. In the area most of the 150 km wide land strip along the coast is less than 2 m above sea-level, and is protected from flooding by a 1 to 10 km wide coastal sand belt only. Research area is also a breeding and nesting area for three globally threatened sea turtles; *Caretta caretta*, *Chelonia mydas*, and *Trionix triunguis*. [14]. This coastal zone is important not only for sea organisms, but also for some endemic vegetation. A type of Aleppo pine (*Pinus halepensis*), not common in Turkey, can be seen in this area, and it is surrounded by sand dunes and lagoons with wetlands with a high floristic diversity [26]. There are also some endemic halophytic plants in the area [23-5]. Figure 2 represents land use for study area coastal zone.

MATERIALS AND METHODS

An initial requirement for the analysis of flooding impacts was the development of spatial datasets. Extensive assessments of sea level rise need exact maps of the whole coastal zone but map scales and accuracy can be change-by nation. In this research, 1:25.000 scale digital elevation contour maps (DECM) was used for creating digital elevation model (DEM). DECM was produced by General Command of Mapping (GCM) in Turkey. General Command of Mapping of Turkey produces various types of maps such as 1:1.00.000, 1:250.000 and 1:100.000 scales. The series of 7.5 min. and 1:25.000 scale map sheets of GCM are the best national maps and data sources for evaluating sea level rise in Turkey. Although these map contour intervals are generally 2.5 m which is more than twice the rise in sea level expected in the next century in the south eastern of Turkey, several of the very low-lying deltaic and more populated zones like research area have 1 m or less than 1 m elevation and topographic information. The GCM 7.5 minute maps have a root mean squared error (RMSE) of ± 5 m. Yet, this error is not equally scattered. On account of the interpolation methods used in obtaining the DEM from 7.5 minute topographical maps, it is acceptable to suppose that such error will be small in relatively flat terrain and large in rapidly changing terrain. Since research area is extremely flat, DEM is likely to have smaller error than average. On the other hand, high accurate maps have been impossible given research budget limitations. Other data specification was given Table 2.

Table 2. Data specifications

Data Name	Data type	Scale	Producer
Digital elevation contour	Vector	1:25.000	General Command of Mapping
Topographic map	Raster	1:25.000	General Command of Mapping
-Soil	Vector	1:25.000	Governorship of Adana, GIS Department.
-Geology			
-Hydrology			
-Land use			
-Land use capability			
-Infrastructure (roads, transformer, power line, bridge, school, hospital, oil station, irrigation canal etc.)			
-Erosion			
-Settlement			
-Population	Table		

The GIS model was used in this assessment by using spatial coastal data combined with common sea level rise projections. GIS data model and procedures were given in Figure 3.

In order to create digital elevation model, spatially joined twenty eight contour line sheets were transformed from line to elevation point (Figure 4).

These map sheets border was also interpolation boundary. Elevation points were interpolated by using natural neighbour algorithm. Natural neighbour interpolation algorithm was used for creating digital elevation model from elevation points. This algorithm is a geometric assessment technique that uses natural neighbour regions generated around each point in the data and it is particularly effective for dealing with a variety of spatial data subjects presenting assembled or highly linear distributions [27]. As a result of interpolation, DEM with 25m cell size was created (Figure 5).

Grid form of DEM was re-classed as 0-1, 1-2 and 2-3 m elevation zone and was transformed to vector layer. Land use, settlements and various maps were clipped with these vector layers so as to determine features and areas in the 0-3 m land elevation.

RESULTS

Cukurova delta coastal zone elevation to sea level rise was illustrated by using Digital Elevation and GIS model. As a result of the analysis of DEM data, approximately 101.399 ha of land area lies below 3 m contour line in Cukurova Delta, and is hence highly vulnerable to sea-level rise. Figure 6 show us land use and infrastructures in 0-1m, 0-2 m, 0-3 m, 1-2 m, 2-3m and 1-3m elevations.

The DEM presented in Figure 5 shows that low-lying land is more extensive at the wetland and agricultural areas of the delta. The areas lower than 3m above sea level, which are at risk of inundation are dunes, wetland, agriculture, pasture, settlement and infrastructure area of whole delta.

It is estimated that a 0-1 m rise would cause flooding in approximately 52.447 ha land area. This land consists of wetlands, sand dune, salt marshes-swamp and pasture, wetlands covering the biggest area. Especially the coastal wetlands and beaches of Akyatan and Yumurtalik Ramsar Area function as a globally significant resting, feeding and reproduction stopover for millions of shorebirds migration flyway. These same wetlands also provide essential spawning and nursery area for commercial fish species.

On the other hand, most of the secondary houses (summer house) are located in Karatas region under 1 m contour line and they are constructed nearly over the coast line. This suggests that secondary houses would be negatively affected in case of the sea level rise.

Considering population and infrastructures, 3313 person lives in 7 settlements under 1 m contour line in Cukurova Delta coastal zone. These people are using as infrastructure 15 transformers, 23 bridges, 6 schools and 1 oil-station (Table 3). According to the census between 1996 and 2004 annual population increase rate is 13.8%o for this region, which means that this population will be around 13.200 until the next century.

The area under 0-2 m contour line various land use classes were presented in Table 3. Approximately 68.799 hectare of land area lies below between 0 and 2 m contour line. These areas have agricultural land utilization because of their highly favourable geomorphic terrain, productive soil cover and abundant water supply. This part of delta with rich alluvial soil, which gets enriched annually, and irrigation network of canals and tube wells support multiple cropping pattern providing relatively high crop yields. Agricultural land (with or without irrigation) covers area of 12.935 ha, sand dune 3.421 ha, salt marshes 2.594 ha, pasture 4.125 ha and settlements 71 ha. On the other hand there are 3.313 people who live in 8 settlements under between 0 and 2 m contour line in Cukurova delta coastal zone. These people are using as infrastructure 18 transformers, 40 bridges, 1 health offices and 7 schools (Table 3).

The area between 0 and 3 m contour line has totally 101.399 ha coast lands which comprise wetlands 35.430 ha, agricultural land (with or without irrigation) 32.393 ha, pasture 13.202 ha, sand dune 4.351 ha, salt marshes – swamp 3.368 ha, settlements 295 ha and river, road etc. and no data area 12.357 ha.

Table 4. Socio-economic characteristics of between 0 and 3 m contour line.

0-3m Sea Level	
Industry	Coal-Thermal Power Plant Petroleum Filling and Pumping Facility Fertilizer Plant
Urbanisation rate (%)	24.7
Population increase rate (%o)	13.8
Population density (person/km^2)	38
Employee rate for Agriculture (%)	82
Employee rate for Industry (%)	2.7
Employee rate for Service sectors (%)	14.8
Unemployed rate (%)	4.5
Tax contribution (%)	0.005
Agricultural production rate (%)	0.76

Table 3. Land use and infrastructure between 0 and 1m, 1 and 2m, 2 and 3m and 0 and 3 m contour lines.

Landuse-Infrastructure	Sea Level					
	0-1 m (52.447 ha)	0-2 m (68.799 ha)	0-3 m (101.399 ha)	1-2 m (16.352 ha)	2-3 m (32.600 ha)	1-3 m (48.952 ha)
Wetland (ha)	35.430,00	35.430,00	35.430,00			
Agriculture (ha)						
Dry	3.940,61	10.158,12	24.074,22	6.217,51	13.916,10	20.133,61
Irrigation	1.716,51	2.777,69	8.319,26	1.061,18	5.541,57	6.602,75
Sand dune (ha)	2.271,34	3.421,34	4.351,28	1.150,00	929,94	2079,94
Salt marshes-swamp (ha)	1.976,60	2.594,55	3.368,50	617,95	773,95	1391,9
Pasture (ha)	4.025,30	4.125,40	13.202,37	3.700,10	5.476,92	9177,02
Settlement (ha)	40,27	71,19	295,40	30,92	224,19	255,12
River, road, power line etc. – No data	3.046,31	6.620,64	12.357,974	3.574,33	5.737,32	4.147,65
Soil Class (ha)						
I			3748,300			
II			4047,430			
III			2318,480			
IV			7732,490			
V			445,918			
VI			18659,100			
VII			11619,000			
Population (person)	3.313	3.313	6027	-	2.714	2.174
Settlement (number)	7	8	21	1	13	14
Transformer station	15	18	46	3	28	31
Water source	-	-	1	-	1	1
Bridge	23	40	182	17	142	159
Health office	-	1	2	1	1	2
School	6	7	19	1	12	13
Oil station	1	1	1	-	-	

Socio-economic structure of 0-3 m contour line was given Table 4. Existing socio economic conditions in the area characterized urbanisation 24.7 %, population increase rate 13.8 %o, population density 18 person/km^2, employee for agriculture 82 %, employee for industry 2.7 %, employee for service sectors 14.8 %, unemployed 4.5 %, tax contribution 0.004635 % and agricultural production rate 0.757070 %. Agriculture is main sector with employee rate of 82 % in the area. On the other hand there are three industrial facilities sitting under 3 m contour line. These are coal based thermal power plant, petroleum filling and pumping station with two marine terminal and fertilizer plant with a marine terminal. Free zone (tax and other economical rules free zone) is also located in this area.

In this research sea-level rise was simulated based on a series of land elevations (0-1, 0-2 and 0-3 m) for the years 2000 to 2100 adopted by the Intergovernmental Panel on Climate Change. Relative rise in sea-level along the Turkish coast, which is of the order of 4–9 mm/year over 20 years, will likely be accompanied in future by a retreat of the shoreline due to erosion or inundation [1]. In order to assess land vulnerable due to sea level rise, digital elevation and GIS data model, various digital and socio-economic data and natural neighbour interpolation algorithm and basic GIS methods were used.

At the end of the analyses it was estimated that as an important wetland and agricultural zone of Turkey, Cukurova delta coastal zone would be very vulnerable to sea level rise and flooding at the physical, land use and socio-economic sense. Having determined the land loss due to inundation, the impacts of this loss were evaluated for the major socio-economic sectors (urban areas, agricultural and wetland land) and for the natural ecosystems at risk; this was undertaken by overlaying maps for both inundation scenarios and land use.

DISCUSSIONS

In the Mediterranean Region, the greatest potential land losses are along south-eastern Mediterranean coast of Turkey, including the Cukurova delta plain is the most vulnerable area for potential land losses in case of sea level rise [10-11]. At these levels, major portions of Cukurova Delta coastal zone would be permanently inundated over the next century. A 1-m sea level rise would result as a great increase in coastal flooding, storm damage, erosion, and salinisation along the Mediterranean Seas, especially the low-lying deltaic areas [12]. Results of the model shows that there are major portions of the coastal zone in Adana region, settlements and population that would be affected by inundation in case of the sea level rise due to the climate change.

Various factors make the Cukurova delta coastal zone highly vulnerable to inundation. These are characterized by flat coastal plain, softly sloping shoreline, sandy beaches, wetlands and salt marshes, which produce extensive shoreline displacement with relatively small rises in sea level. For instance, in this study under the 3 possible sea-level rise scenarios the agricultural land loses calculated as 5.657 ha for 0-1 m rise, 12.935 ha for 0-2 m. rise and 32.393 ha for 0-3 m rise in research area. To represent the clear negative effects of these 3 possible scenarios on agricultural production, it is accepted that wheat cultivation is practicing in all the agricultural lands which is one of the primary agricultural product in the area. In the study area, because of appropriate soil and climate conditions, the wheat yield is 3.590 kg/ha where the average wheat yield for the Turkey is 2.670 kg/ha [22]. The world price of the wheat is accepted as 264 dollar/tons which is the average world price for the year 2012 [9]. As a result of these assumptions, there will be 20.308 tons and $5.361.312 lose under the first sea level rise scenario (0-1 m), 46.436tons and $12.259.104 lose under the second sea level rise scenario (0-2 m) and 116.290 tons and $30.700.560 lose under the third sea level rise scenario (0-3 m).

There are several options for managed retreat and accommodation strategies in Turkey. For instance, land-use planning in coastal zones, such as using building setbacks or allocating low lying vulnerable lands to lower value uses (i.e., parks rather than tourism), would help reduce the overall vulnerability to sea-level rise as well as current coastal hazards. Such a measure however has not been seriously considered in Turkey.

Turkey, being a coastal country, recognized the increasing number of problems in coastal zones and many safety measures are being taken by several governmental institutions and agencies [17]. For example, most of the areas declared as protection zone by the Turkish government are located in the Aegean and Mediterranean coast. In the short term, for the struggle of negative impact of sea level rise, The Ministry of Environment should declare new areas as protection zones and develop special national level environmental programs.

Acknowledge

I would like thank Dr. Tuncay KULELİ for helping me on creating methodology and displays of the article.

REFERENCES

[1] Alpar, B., 2009. Vulnerability of Turkish coasts to accelerated sea-level rise. Geomorphology, 107, 58–63

[2] Behnen, T., 2000. Der beschleunigte Meeresspiegelanstieg und seine sozioökonomischen Folgen: Eine Untersuchung der Ursachen, methodischen Ansätze und Konsequenzen unter besonderer Berücksichtigung Deutschlands. Hannover, Germany: Hannoversche Geographische Arbeiten 54, 224.

[3] Brown, I., 2005. Modelling future landscape change on coastal floodplain using rule-based GIS. Environmental Modelling and Software 1-12.

[4] Chen, S., Chen, L., Liu, Q., Li, X., Tan, Q., 2005. Remote sensing and GIS-based integrated analysis of coastal changes and their environmental impacts in Lingding Bay, Pearl River Estuary, South China. Ocean and Coastal Management 48, 65-83.

[5] Demirkesen, A. C., Evrendilek, F., Berberoglu, S., 2008. Quantifying coastal inundation vulnerability of Turkey to sea-level rise. Environ Monit Assess, 138:101–106

[6] Douglas, B. C., Kearney, M. S., and Leatherman, S. P., 2001. Sea Level Rise: History and Consequences. The International Journal of Marine and Coastal Law 16, 3, 531-533.

[7] Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, P.J., and Xiaosu, D. (Eds.) Climate Change (2001) The Scientific Basis, Contribution of Working Group I to the

[8] Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) Cambridge University Press, New York.

[9] IGC (International Grains Council), 2013. http://www.igc.int/grainsupdate/igc_goi.xlsb (accessed December 15, 2012).

[10] Kuleli, T., 2010. City-Based Risk Assessment of Sea Level Rise Using Topographic and Census Data for the Turkish Coastal Zone. Estuaries and Coasts, 33:640–651

[11] Kuleli, T., Senkal, O., Erdem, M., 2009. National assessment of sea level rise using topographic and census data for Turkish coastal zone. Environ Monit. Assess, 156:425–434

[12] Karaca, M., Robert J. Nicholls, J. R., 2008. Potential Implications of Accelerated Sea-Level Rise for Turkey. Journal of Coastal Research, 242:288-298

[13] Karaca, M., 2000. Implications of Accelerated Sea-Level Rise (ASLR) for Turkey. Proceeding of SURVAS Expert Workshop on European Vulnerability and Adaptation to impacts of Accelerated Sea-Level Rise (ASLR) Hamburg, Germany, 19th-21st June, 29-31.

[14] Kasparek, M., 1991. Distribution and bionomics of the Nile Soft-Shelled Turtle, Trionyx tringuis, in the Eastern Mediterrranean . Zeitschr. f. angew. Zool.78, 139 - 159.

[15] Meehl, GA., Stocker ,T F., Collins, W., Friedlingstein, P., Gaye, A., Gregory, J., Kitoh, A., Knutti, R., Murphy, J., Noda, A., Raper, S., Watterson, I., Weaver, A., and Zhao, Z., 2007. Global climate projections. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon S, D Qin, M Manning, Z Chen, M Marquis, KB Averyt, M Tignor and HL Miller, Eds., Cambridge University Press, Cambridge and New York.

[16] Marchnand, H., 2006. Impact of the tsunami on a Marine National Park area-Case study of Lanta Islands (Thailand). Ocean and Coastal Management 49, 923-946.

[17] MoEF, 2007. First National Communication of Turkey on Climate Change. Editors Apak G., Ubay B. The Ministry of Environment and Forestry (MoEF), General Directorate of Environmental Management, Ankara, Turkey.

[18] Nicholls, RJ., 2003. Case Study on Sea Level Rise Impacts. Prepared for OECD workshop on the Benefits of Climate Policy: Improving Information for Policy Makers: December 12-13, 2002, Working Party on Global and Structural Policies, Organization for Economic Cooperation and Development, Paris.

[19] Nicholls, RJ., Hoozemans, F.M.J., and Marchand, M., 1999. Increasing flood risk and wetland losses due to global sea-level rise: regional and global analysis. Global Environmental Change, 9, 69-87.

[20] Titus, J.G., and Richman, C., 2000. Maps of Lands Vulnerable to Sea Level Rise, Modelled Elevations along the U.S. Atlantic and Gulf Coasts, Climate Research 18, 205-228.

[21] Tsimplis, M.N., Woolf, D.K., Osbourn, TJ., Wakelin, S., Wolf, R., Flather, P., Woodworth, A.G.P. Shaw, P., Challenor and Z Yan., 2004. Future changes of sea level and wave heights at the northern European coasts Geophys. Res. Abs., 6, 00332.

[22] TUIK (Turkish Statistical Institute), (2013).

http://rapor.tuik.gov.tr/reports/rwservlet?hayvancilik=&report=BARAPOR23.RDF&p_yil1=2011&p_kod=1&p_mad1=1110115&p_dil=1&desformat=html&ENVID=hayvancilikEnv

[23] Uslu,T., Salman, AHPM., Doody, J.P., 1993. Conservation aspects of coastal dunes in Turkey. EUCC Internal report series no.5, EUCC, Leiden.

[24] Warrick, R.A., Oerlemans, J., Woodworth, P.L., Meier, MF., Provost, C., 1996. Changes in sea level. In: Houghton JT, Meira Filho LG, Callander BA, (Eds.) Climate Change (1995) The Science of Climate Change. Cambridge University Press Cambridge UK.

[25] Woodworth, P.L., Gregory, J.M., and Nicholls, R.J., 2005. Long term sea level changes and their impacts. The global coastal ocean: multiscale interdisciplinary processes, Robinson AR, and Brink K H, Eds., Cambridge, Massachusetts, 715-753

[26] Van der Have, T.M., Van Den Berk, V.M., Cronau, J.P., Langeveld, M.J., 1988. South Turkey Project: A survey of waders and waterfowls in the Çukurova Deltas. Dutch Society for the Protection of Birds, WIWO Report No:22, Holland.

[27] Vertical Mapper User Guide, 2001. Northwood Technologies Inc. and Marconi Mobile Limited 2001 Printed in Canada