Coastline Change Detection using Remote Sensing and GIS at TONEKABON Coast Area during 1984 and 2010, MAZANDARAN PROVINCE, IRAN

Saddrodin Motevalli [1,*], Mohammad Mahdi Hosseinzadeh [2], Khabat Derafshi [3], Saideh Gharehchahi [3], Moharam Ali Alijani [4]

[1.] Assistant Prof. of the Geography, Department of Geography, Nour Branch, Islamic Azad University, Nour, Iran
[2.] Assistant Prof. of Faculty of Earth Sciences, Shahid Beheshti University, Tehran, Iran
[3.] M.Sc of Geomorphology, Shahid Beheshti University, Tehran, Iran
[4.] M.Sc of Geomorphology, Department of Geography, Nour Branch, Islamic Azad University, Nour, Iran
*Corresponding Author Email: Sadr_m1970@yahoo.com

Abstract: The coast is a special place on which Atmosphere, Hydrosphere and Lithosphere are in contact to each other. Coastline is one of the most important linear features on the Earth's surface showing a dynamic nature. The coast and its environmental management need information on coastline and its changes. Regarding to the sea level changes in the recent century, the coastline changes issue has introduced more consideration of social, economical and environmental aspects at Tonekabon coastal area, and has created some problem for the environment and residential areas. In this study, the common approaches for determination of coastline changes through Remote Sensing (RS) and Geographical Information System (GIS) techniques and also Satellite Images has been applied on Tonekabon coastline. The TM, ETM and ETM+ landsat satellite images in 1984, 2000 and 2010 were selected, and their geometric and radiometric error correction were done at pre-processing stage. At image processing stage, Band #5 being the best band of detecting water from land, and contrast enhancement, Thresholding and edge detecting filter as the best separation approaches were applied. Outputs in the form of raster layers, showed a zigzag-like coastline from 1984 to 2000 and 2010. Afterwards, raster data were converted into vector, and position changes of coastline for 41 points with an equal space of 1000 m were measured. Results showed an average displacement of 75.2 m toward coast during 1984 and 2000. The average change, during 2000 and 2010, was determined 32.9 m. In these years, most of the study area has encountered a retrograde water level and expansion of land and only in a few places small values of rising in sea level has been observed. In order to evaluate the accuracy of the applied methods in extraction of coastline and its change measurement, field measurement was also taken that Building destruction by sea waves, sinking several buildings under water, protecting of buildings against sea expansion and so on, are some witness for the methodology accuracy of this study in the coastline changes issue at Tonekabon City.
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1. INTRODUCTION

The coastal areas are always physically and ecologically changing that depends to natural and human factors. Natural factors of coastline changes are evaluated through three methods: short term changes including the effects of increasing and decreasing of flow; long term changes including climate variation, temporal storms and waves; and random changes including natural unexpected events (Tağil and Cϋrebal, 2005; Krueger, et al, 2008). These happened changes would affect on coastline changes and coastal areas, and in future would negatively affect on human and human activities and sea communications (Bayram, et al., 2004; Tai-Wen, et al., 2007).

Monitoring of coastal areas is an important fact in steady development and environment maintenance. To monitor a coastal area, coastline extraction in various times is an essential task (Alesheikh, et al., 2007). Coastline is one of the most important linear features on the Earth's surface showing a dynamic nature (Winarso, et al., 2001). Coastlines are introduced as one of the most important geographical features on the Earth's surface by International Geographical Data Committee (IGDC), geographically are the intersection of coastal area and the sea water (Kurt, et al, 2010). Accordingly, it is important to produce coastline map and to determine the changes for a secure shipping, resource management, environment maintenance, planning and coastal steady development (Di, et al., 2004).

Literature review of so far done researches related to the monitoring of coastline change could be explained as following: from 1807 to 1927, all coastline maps were produced through field measurements. In 1927, real potential of aerial photos to complete the coastline maps was understood.

During 1927 to 1980, aerial photos were considered as the most especial for producing those maps. However, too many photos needed to produce a regional coastline map, and being expensive and too much time taking of gathering, correcting, analyzing and transferring the data and also being white and black photos are considered as their limitations (Lillesand, et al., 2004). Beside these limitations, not being digital photos, having low temporal coverage and low geometric accuracy could also be mentioned. Progressing the evolution of the researches related to the changes of coastline monitoring, satellite image and remote sensing techniques and Geospatial Information system were entered and applied on this field of study having more accuracy, vast spatial and temporal coverage and accurate and understandable outputs and so on. Remote sensing and Geospatial Information System have economically an important role on acquiring spatial data (Alesheikh, et al., 2003). Optical satellite images are easy to acquire and interpret. Furthermore, Infra Red wave length absorption by water and the ability of vegetation and soil in their intensive reflection, have converted these images to an ideal combination for producing the spatial map of land and water distribution. These characteristics of water, vegetation and soil has prepared the ability of applying images containing visible and IR bands to produce coastline maps (DeWitt, et al., 2002). Of new studies done related to this issue could be mentioned such as determination of coastline change using Remote Sensing (Alesheikh, et al., 2007); Coastline changes at Istanbul during 1987 and 2007 (Kurt, et al., 2010); and Coastline change and sea level rising along Bhitarkanika coast: analytical point of view of Remote Sensing and Statistical techniques (Chand and Acharya, 2010).

During the past decades, Tonekabon coastal area has encountered considerable changes of coastline indebted to the Caspian Sea's waves and rapidly getting industrialized and urbanized. Regarding to the fact of sea level changes in the last century, coastline changes in this area has introduced more consideration to the social, economical and environmental aspects, and has brought along some environmental and residential problems in Tonekabon coastal area. Thus, in this study we have tried to apply the common determination methods of coastline changes using Remote Sensing and Geospatial Information System techniques and also TM and ETM+ satellite images at Tonekabon City during 1984 to 2010, and to analyze and assess the coastline changes of the study area.

2. THE STUDY AREA

Tonekabon City with an area of about 2114 km2 lies in 51° 17′ to 51° 31′ eastern longitudes and 36° 15′ to 36° 52′ northern latitude (figure 1). From north, Tonekabon City is restricted to the Caspian Lake, the biggest lake of the world, from south to the Alborz Mountains and Qazvin Province, from east to Challoos City and from west to Ramsar City; the Chalk rood is the border between these two cities. Northern parts of the city is surrounded by a narrow coastal plain which has a varying width of 1 to 9 km. Due to a relatively enormous amount of rainfall and surface and groundwater flows, the city has a dense vegetation. A plain part of the city is covered by forest which has been converted to farmlands of tea and rice and fruit gardens.

3. DATA AND METHODOLOGY

Remote sensing is one of the best and most reliable methods in monitoring and management of environment and resources (Doygun, et al., 2003; Maktav and Erbek, 2005; Duran, et al., 2006; Deng, et al., 2008; Karaburun and Demirci, 2009). Various methods have been created to extract coastline from satellite images. Since the reflection of water in IR bands are almost Zero and most of vegetation have a bigger reflection versus water, coastline can be extracted from even one band of the image. This extraction can be achieved from thresholding on one IR band of TM and ETM+ images. Thus, in this study we have used satellite images of TM, ETM and ETM+ Landsat in the years 1984 (Sep 19), 2000 (Jul 25) and 2011 (Aug 1) to monitor the coastline changes of Tonekabon City. Characteristics of spectral and temporal resolution index of various bands of these images are illustrated in table 1.

3.1 PRE-PROCESSING AND SATELLITE INTERPRETATION

Selection of an appropriate spatial and temporal image is an essential step to investigate any changes, and consequently to analyze them. Landsat satellite image with a spatial resolution of 30 m and IRS with a resolution of 22.5 and 5 m, are some of the best and most important tools in investigation of coastline changes. Investigation of coastline changes of Tonekabon City in 1984, 2000 and 2011 was taken using Landsat satellite images. Applying pre-processing on these images, spatial and radiometric amplifying was done, and separately analyzing each band and also in combination with various bands, the best band or combination of bands were selected to detect and control the ground points. Afterwards, determining the checkpoints on images and topographic maps, image georeferencing and geometric correction were done.

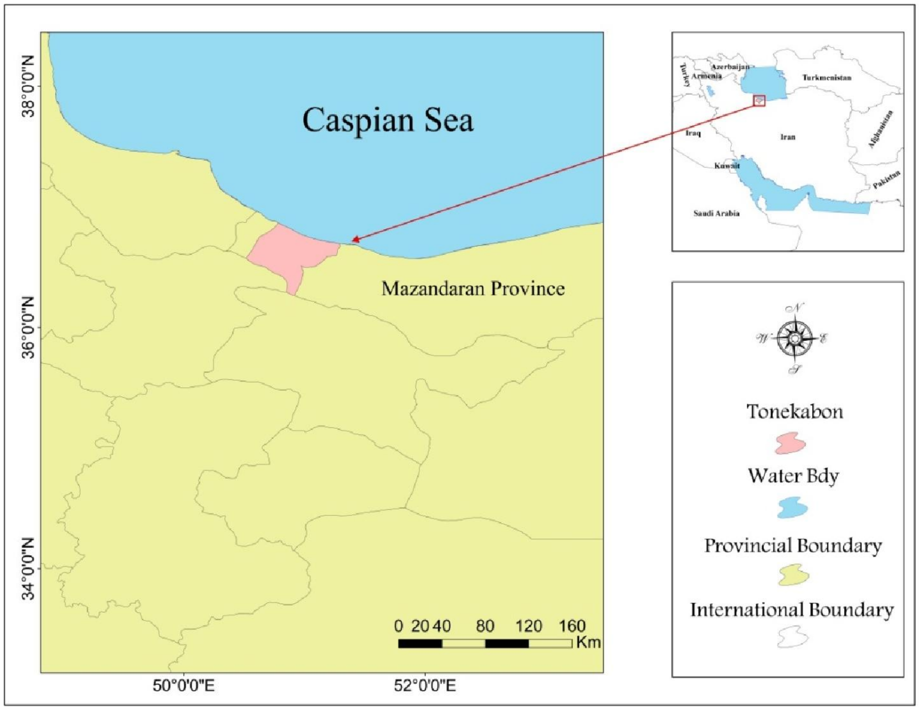

Fig 1. Geographical location of Tonekabon City

Table 1. Spectral and temporal resolution index of Landsat 7 (ETM+) and Landsat 5 (TM)

Band No.	Spectral range (Microns) ETM+/TM	Spatial resolution (m) ETM+/TM
1	.45 to .515 / .45 to .52	30
2	.525 to .60 / .52 to .60	30
3	.63 to .69 / .63 to .69	30
4	.75 to .90 / .76 to .90	30
5	1.55 to 1.75 / 1.55 to 1.75	30
6 (L/H)	10.4 to 12.5 / 10.5 to 12.4	60 / 120
7	2.09 to 2.35 / 2.08 to 2.35	30
Pan	.52 to 90 / Nil	15 / Nil

3.2 SATELLITE IMAGE PROCESSING AND WATER-LAND SEPARATION ALGORITHM

This step has an important effect on analyses, and needs the highest level of accuracy in determination of the best algorithm to separate and distinguish coastline in satellite images. Best spectrum of the electromagnetic waves for separation of water from land is IRS. IR wave's absorption by water and its large amount of reflection by vegetation and to some extent soil, create a strong contrast between water and land. Owning separate bands in visible and IR spectra, Landsat satellite images prepare good choices for users. By analysis of spatial profile in different bands of TM and ETM+, it can be concluded that in bands with visible wave length (bands 1, 2 and 3) and Thermal IR (band 6) there is no considerable difference between water and other features; but bands 5 and 7 have the most differences, and for further mono-band-based studies these bands have been used. For this purpose, application of bands 5 and 7 has been recommended by several researches. After selection of appropriate bands, in order to separate land and water, various methods can be applied as follow:

Contrast enhancement; if limitation of gray steps is such varied that get expanded in all black and white axes, a situation would create that relative distribution of gray steps is constant and the contrast between dark and light areas would increase. Previous studies used various methods have showed that because there exists a complete amplitude of pixel's brightness (0-255), linear expansion of contrast would not have a considerable effect on crude images of bands 5 and 7; but saturated linear expansion of contrast with a saturation degree of 5 percent has been very effective on band 5 and has created a strong contrast between water and coast. Convenient resolution of images was not also produced using contrast expansion with histogram justification method.

Spatial detection of images or filtering method; operation of detecting and separating some components of digitized images from other parts is called spatial detection of images or filtering. Applying overpass filter on image, high frequency information let us to isolate or amplify the local details (Richards and Jia, 1998). From all overpass filters of ERDAS software, filters of overpass and edge detection with 3*3 have been used.

3.3 SELECTING THE WATER-LAND SEPARATION METHOD

Based on results from amplifying methods, contrast enhancement by saturated linear expansion method is more effective in image amplifying, and band 5 is also effective than band 7 in border separation; but since this method only covers the spectral amplifying, in order to extract a distinct border between water and land, it was used along other completing methods, one common of them is temporal amplifying. Thus, various filtering methods were used that edge detection filter on images of band 5 showed better results versus the others. Because the mentioned filter has less effect on existing features in image, extraction of water-land border and even the flat wet lands and water, especially for band 5, was more convenient. Flowchart of the steps applied on this study is illustrated in figure 2.

4. RESULTS

To determine the dominant coastal processes acted at certain places, analysis of former coastline data using their change values as a witness of dynamicity of coastline can be effective. In this paper, using temporal detection of band 5 of Landsat satellite images in 1984, 2000 and 2010, coastline changes of Tonekabon City were extracted. Figure 3 shows results of spatial amplifying of images by contrast enhancement method along with thresholding and edge detection filter to investigate the coastline changes of the study area. Based on this spatial amplifying, coastline of Tonekabon City during the study years, from nearly a straight linear form in 1984 has changed to a zigzag-sine form in 2000 and 2010 that the main factors are human activities and construction in the area. After amplifying, the obtained coastline from band 5 of Landsat images was converted to vector feature to measure its change values in different parts of the area. Several examples of the vectorized coastline movements in those three years have been showed in figure 4.

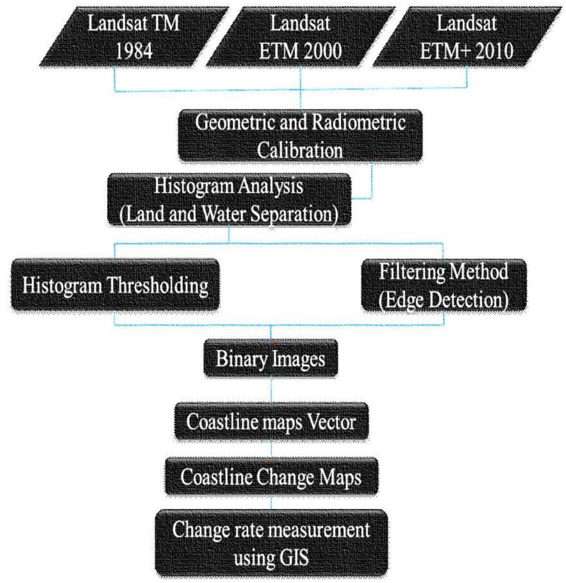

Fig 2. Methodology framework for determination of coastline change

Afterwards, to investigate and determine the spatial changes of coastline, spatial changes from images of 1984, 2000 and 2010 in 41 points with equal distances of 1000 m were measured; results are shown in table 2. Spatial changes of coastline in these 41 points are in such a way that from 1984 to 2000, the area has encountered a raise in sea level toward the land and a decrease of the area in all point, whereas from 2000 to 2010, the coast of city with a decrease in sea level has encountered an increase of area in most parts of the land, and only in distances of 3, 9, 14, 18 and 23 km, the sea has had an increase of the water level toward the land with an average of 15 m spatial change. Interview with natives of the area shows that decrease of sea level and increase of land has occurred 5 years ago.

According to table 2a, minimum and maximum values of spatial change of coastline during 1984 and 2000 are 20 and 204.7 m, respectively, lied in 1 and 6 km of measured coastal changes; average spatial coastline changes in these 16 years is 75.2 m with an annual average movement of 4.7 m of Tonekabon coastline. Based on table 2b, spatial changes of coastline during 2000 and 2010 has been lessened versus the former period, that minimum and maximum values of changes are 0 and 96.1, respectively, lied in distances of 7 and 4 km recorded from the measurement points. Average movement of coastline during these 10 years is about 32.9 m showing an annual coastline movement of 3.3 m in Tonekabon City. Diagram of spatial changes of coastline during the study years along the 41 measurement points is illustrated in figure 5.

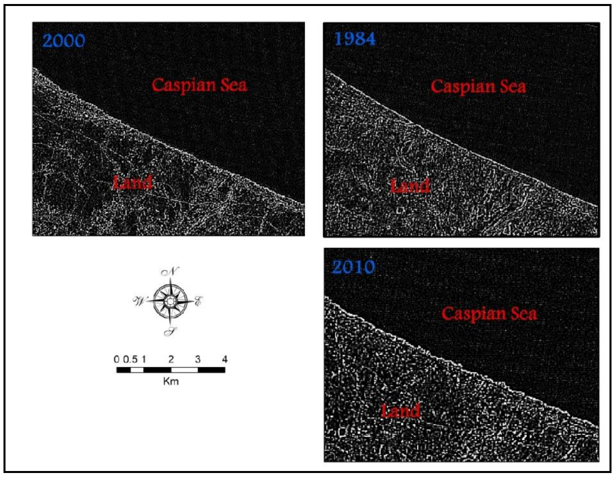

Fig 3. Land-water separation by spatial amplifying of band 5 of Landsat satellite image

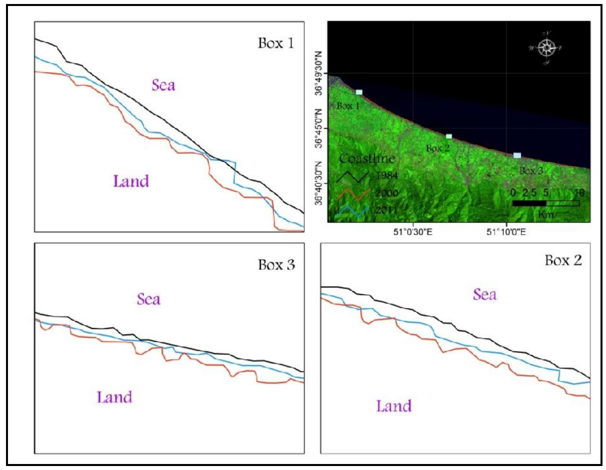

Fig 4. Spatial changes of coastline in Tonekabon City in 1984, 2000, 2010

Table 2a. Spatial movement values of coastline during 1984 and 2000

Distance	Changes (m)	Distance	Changes (m)	Distance	Changes (m)	Distance	Changes (m)
0	24.9	11000	75.9	21000	78.8	31000	83.3
1000	20	12000	114.5	22000	59.7	32000	85.1
2000	39.5	13000	90.4	23000	43.1	33000	31
3000	30.1	14000	45.1	24000	61.1	34000	30.4
4000	103	15000	76.7	25000	110.6	35000	21.3
5000	71.6	16000	82.3	26000	87.1	36000	25.8
6000	204.7	17000	83.8	27000	84.4	37000	63.9
7000	87.9	18000	65.7	28000	114.5	38000	97.8
8000	125.3	19000	111.7	29000	52	39000	82.9
9000	98.1	20000	82.1	30000	55.3	40000	76.8
10000	103.6	-	-	-	-	-	-

Table 2b. Spatial movement values of coastline during 2000 and 2010

Distance	Changes (m)	Distance	Changes (m)	Distance	Changes (m)	Distance	Changes (m)
0	18.06	11000	11.3	21000	36.1	31000	48.28
1000	11.23	12000	53.7	22000	31.6	32000	82
2000	12.56	13000	29.5	23000	12.7	33000	20.2
3000	11.3	14000	0.6	24000	51.8	34000	21.9
4000	96.14	15000	22.4	25000	54.9	35000	21.1
5000	22.1	16000	7.4	26000	12.8	36000	8.8
6000	57.1	17000	28.2	27000	48.7	37000	31.7
7000	0	18000	22.1	28000	90.7	38000	53.3
8000	21.7	19000	58.06	29000	17.95	39000	39.8
9000	29.3	20000	69.3	30000	24.7	40000	21.8
10000	38	-	-	-	-	-	-

5. DISCUSSION AND CONCLUSION

Assessment of accuracy values for the measurements of Tonekabon coastline changes by remote sensing and GIS techniques needs a comparison with the coastline extracted from band 5 of Landsat satellite images or field measurements. Therefore, field measurements in various points have proved the precision of used methods in this study, and will be discussed later. Figure 6 is an example of constructions done after revolution (around 1976) in

Sisaraa (east of Salmanshar). According to rules, at those years the sea limits were 60 m far from buildings, and review with natives shows that this limit had been maintained. Starting the sea advancement toward the coast, these buildings have been affected by the risk of sea waves and most of the have sunk under the water and got ruined. In later years, to protect the buildings, some structures were created that can be seen in figure 6 as concrete blocks.

Figure 7 is also another example of destroyed buildings in sea advancement that at the moment its yard is under the water, and its planting and grass are related to before sea advancement. The location of this building is Asbchin coast that is shown is the Google Earth photo (figure 7).

Measurements of spatial movement of coastline show that during those three study years, from 1984 to 2000 and 2010, zigzagging of Tonekabon coastline has happened and the reason is mainly human activities. Figure 8 is another example of these activities that is also a reason of sea rollback at the construction site of Ghoo Hotel, Salmanshahr.

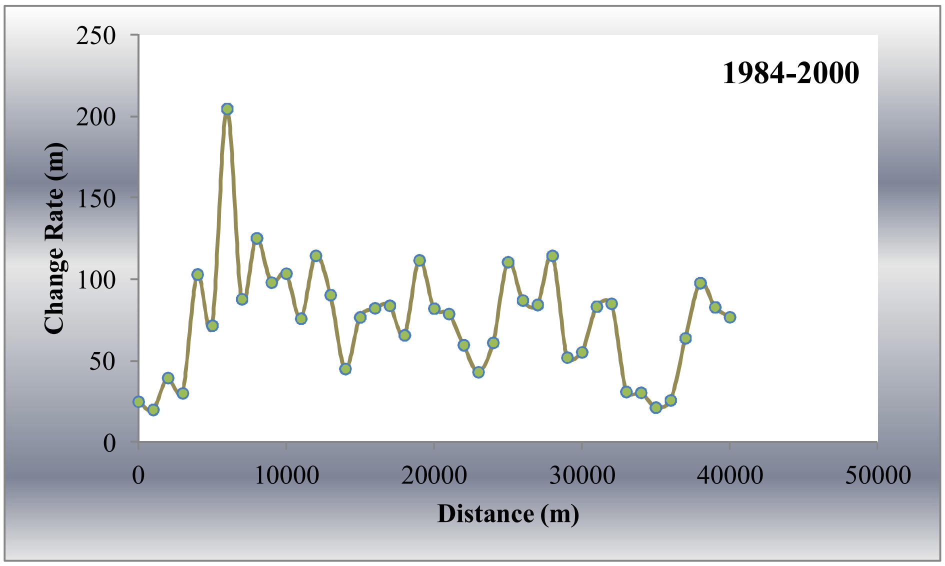

Fig 5a. Diagram showing the spatial changes of coastline during 1984 and 2000

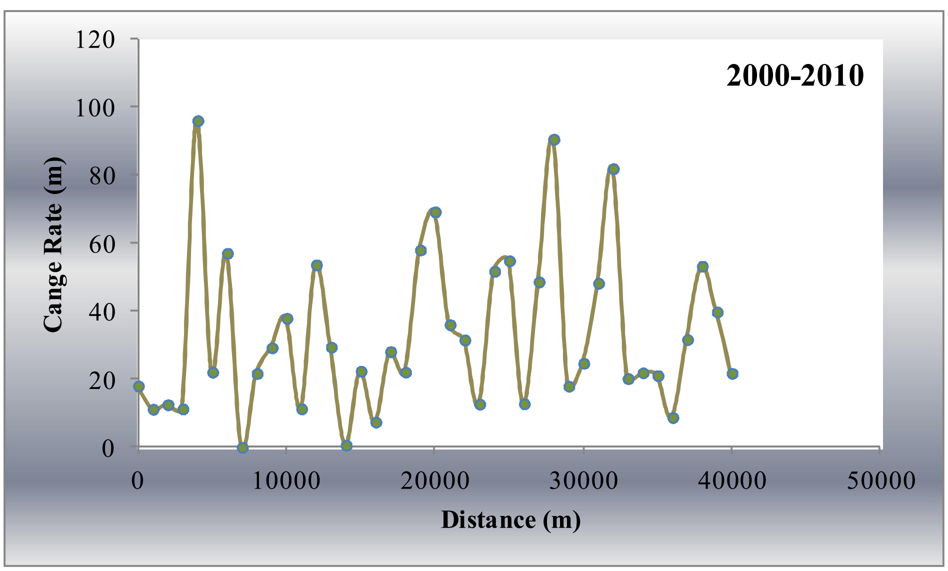

Fig 5b. Diagram showing the spatial changes of coastline during 2000 and 2010

Fig 6. Destroyed buildings in expose of sea waves in Sisaraa coast

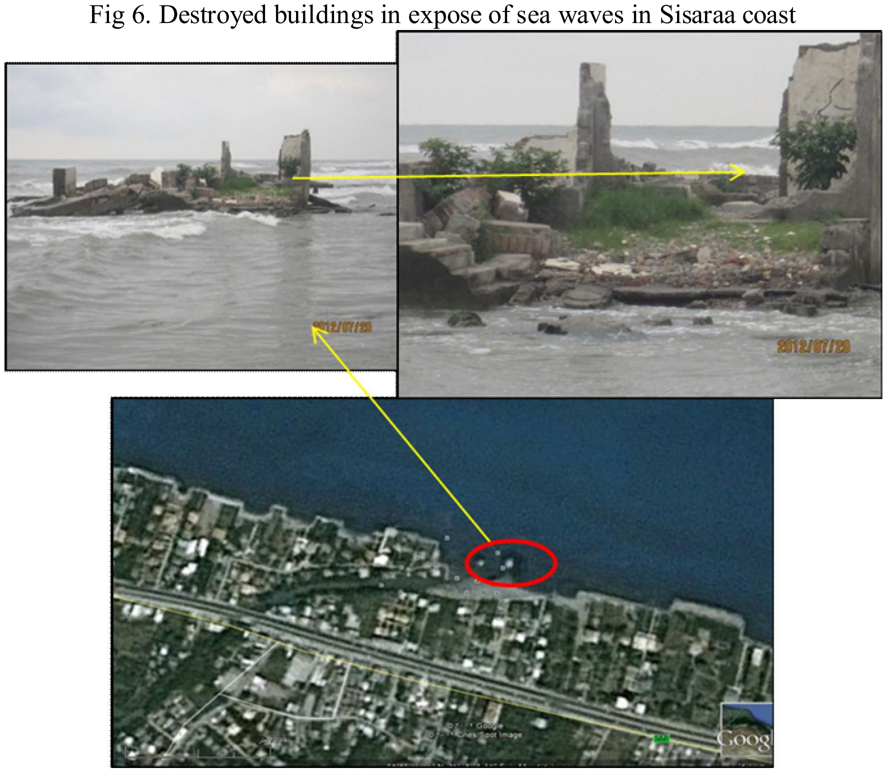

Fig 7. Sinking the building under the water in Asbchin coast because of sea advancement

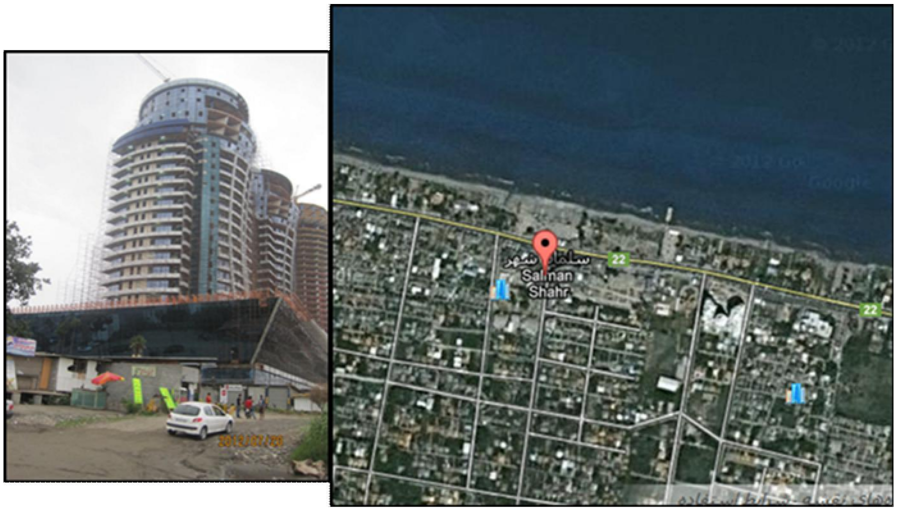

Fig 8. Human, a factor of zigzagging and rolling back of the sea (Ghoo Hotel, Salmanshahr)

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