Science Arena Publications
Specialty Journal of Architecture and Construction
ISSN: 2412-740X
Available online at www.sciarena.com
2019, Vol, 5 (2): 49-71

The Effect of Marine Transgression and Regression on Land Use Changes through Multitemporal Remote Sensing Imageries

Majid Taghipour, Mehran Dizbadi*

M.Sc. of Civil Engineering - Remote Sensing Engineering, Islamic Azad University, Shahroud, Iran.

***Corresponding Author**

Abstract: *The appearance of coastal lands-use is constantly changing due to the transgression and regression of water bodies. This changing of coastal land-uses poses the necessity to continuous monitoring of them within certain temporal ranges to appropriately control the coastal resources. In this study the effect of transgression and regression of Gorgan gulf on the change of land-use was modeled and assessed using remotely sensed multitemporal imageries. To this end, at first two satellite images of Landsat 5 and Sentinel 2 taken in years1992 and 2017 respectively, were received. And after some preparations and required preprocessing implementations, they were classified by the performance of maximum likelihood classifier and the land-uses were extracted from the studied extent. The values of overall accuracy and coefficient of kappa were 0.94 and 0.92 respectively that were representing the acceptable accuracy of maps for extracted land-uses. The classified imageries, topography maps and roads` network were determined as the inputs of land-use change modelers for detecting land-use changes within recent 25years.The results of the current study showed that the water bodies of Gorgan gulf has experienced a reduction about 150 km2 due to regression of water surface and this reduction has resulted in increment of coastal, fallow and bare lands area. Moreover, the land bodies of agricultural, horticultural and postural lands have encountered significant decrease of the surface. Findings of this research can help the regional planners and environmental managers to appropriately do the managements of valuable resources of Gorgan gulf.*

Keywords: *Change Detection, Landsat 5 Imageries, Sentinel 2 Imageries, Remote Sensing, Gorgan Gulf*

INTRODUCTION

The rise of seawater and its transgression and regression along the banks and the gulfs as one of the manifestations of climate change has always threatened coastal and gulf destinations. Flood and inundation of coastal areas, coastal erosion, damage to infrastructure, destruction of coastal installations, and increased human risks are all the threats brought about as a result of transgression. Thus, the study of the effects and repercussions of this transgression and regression on the shoreline lands would result in a better understanding of this natural process in terms of adverse effects. In other words, this may cause a decision to better plan the land-use for these areas, in proportion to the changes imposed on lands at certain intervals. Considering the necessity of knowing the effects of the regression and transgression of areas near the sea on the land-use of neighboring areas, the monitoring and disclosure of land-use changes due to sea level fluctuations is of great importance. It is possible to understand and study these effects at the time, due to the emergence of the technology of natural resources satellites and remote sensing.

Post-classification comparison

This method is the best way to detect changes in two different times in which the amount of change is obtained in two images. The basis for this approach is that the two images taken in different dates are classified separately after applying the required preparations and pre-processings. The images are then placed on each other, so that their changes could be estimated and detected. Obviously, the accuracy of the obtained map largely depends on the accuracy of the classification performed in the original images (Figure 1). This paper utilized this method to detect the changes in the land-use of Gorgan gulf area along its border lands.

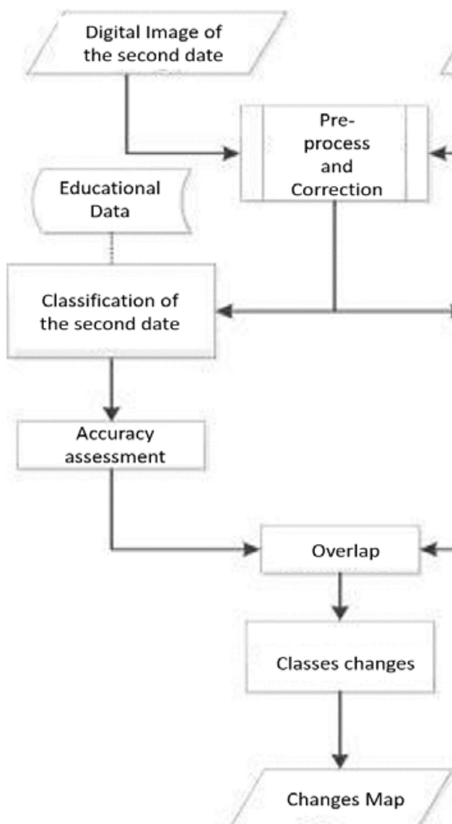

Figure 1. The process of detecting land-use changes by post-classification comparison method.

Literature Review

Kheirkhah Zarkesh and Hosseinzadeh Azad (2016) studied the detection of land use change in Ardabil using remote sensing and GIS. They applied the supervised maximum likelihood classification technique (MLC) to the detection of the land-use change in the developed domain of the Ardabil city. They concluded that the urban development process has dynamically been interfered with the agricultural uses. In addition, the construction has been carried out on the outskirts of the city and nearby villages.

Khoi and Murayama (2010) implemented a combination of Land-use change Modeler (LCM) and artificial neural network to model forest land-use changes. They used satellite images of 1993, 2000, and 2007 as the input of the detection model to predict the forest land-use changes in 2014 and 2021. The results indicated that the level of lands covered by forests during the 2007-2021 periods significantly decreased.

By adopting a management approach based on a combination of remote sensing and GIS, Ahmed et al. studied the dynamics and the land-use changes in Bangladesh. They concluded that a mixture of the study area and the hydrodynamic scenarios combined with remote sensing and GIS can be fruitful for further analysis of the dynamics and for integrated management of coastal lands.

Kaliraj et al. (2017) studied the land-use change and conversion and land cover in coastal areas using remote sensing and GIS. They used the MLC in their study and concluded that over the past decades, the factor increasing the area of residential regions has had destructive effects on coastal resources which has been directly proportional to the growth of the population.

Materials and Methodology

Maximum Likelihood Classifier

The maximum likelihood classification is the most common supervised classification algorithm based on the estimation of the maximum likelihood of the unknown pixel class membership using the multivariate normal distribution models for the classes. Suppose that the spectral classes are represented as follows.

$$w_i, \quad i = 1, \dots, M \qquad (1)$$

where **M** is the total number of classes. To determine the class or category to which that the pixel vector **X** belongs, the conditional probability is given as follows.

$$\boldsymbol{p}(w_i|x), \quad i = 1, \dots, M \qquad (2)$$

where **X** is a column vector of brightness values of pixels. In this case, each pixel is described as a point in a multi-dimensional space. $\boldsymbol{p}(w_i|x)$ is a probability that the class w_i is a pixel in position **X**. The classification is done as follows:

$$\boldsymbol{p}(w_i|x) > \boldsymbol{p}(w_j|x) \ \ for \ \ all\ i \neq j \quad (3)$$

That is, if $\boldsymbol{p}(w_i|x)$ is maximum, the pixel **X** will belong to the class w_i.

According to the Bayesian probability theory:

$$p(w_i|x) = \frac{p(x|w_i)p(w_i)}{p(x)} \qquad (4)$$

where $p(w_i|x)$ is the probability of the occurrence of w_i in the image (anterior probability), $p(x|w_i)$ is the probability of finding a pixel of the class w_i in position $p(x)$, X is the probability of finding a pixel of each class in the X position, and $p(w_i|x)$ is the posterior probability. Therefore, the classification rule can be written as follows:

$$x \in w_i \ \ if \ \ p(x|w_i)p(w_i) > p(x|w_i)p(w_j) \ \ for\ all\ i \neq j \qquad (5)$$

This rule is more acceptable than the eq. (3) because $p(x|w_i)$can be calculated from the training data and the value of $p(w_i)$ i is either known or calculated by the analyst's knowledge of the image.

The parameters that have been used to validate the results are as follows:

The overall accuracy equals the ratio of the total number of samples on the original diagonal to the total number of samples. In eq. (6), **Ac** is the overall accuracy, x_{ii} is the class in the main diagonal matrix and **N** is the total number of samples.

$$Ac = \frac{\sum_{i=1}^{N} x_{ii}}{N} \qquad (6)$$

The user's accuracy equals the ratio of the correctly classified elements for each class to the sum of the number of elements on the row indicating that class. If we subtract this accuracy from 1, the commission error would be achieved.
The producer's accuracy equals the ratio of the correctly classified elements for each class to the sum of the number of elements on the column indicating that class. If we subtract the producer's accuracy from 1, the omission error would be achieved.
The Cohen's Kappa statistic: It measures the difference between the observed agreements between the two maps, such as those reported in the diagonal numbers on the reported error matrix and the agreement that may be achieved only in two maps (Powell et al., 2007).

$$k = \frac{N.\sum_{i=1}^{N} x_{ii} - \sum_{i=1}^{N}(x_{i+}x_{+i})}{N^2 - \sum_{i=1}^{N}(x_{i+}x_{+i})} \qquad (7)$$

In eq. (7), k is the kappa statistic or coefficient, and x_{i+} is the sum of elements on the ith row while x_{+i} is the sum of elements on the ith column. The kappa coefficient values range from -1 to 1, and the closer it is to 1 the higher the accuracy of the classification.
The least squares error: to compute the **RMSE** of the frequencies images of the reference members, the following formula is used:

$$RMSE = \frac{1}{m}\sum_{k=1}^{m}\sqrt{\sum_{j=1}^{m}\frac{(r_{jk} - r'_{jk})^2}{n}} \qquad (8)$$

In this formula, **m** is the number of bands, **n** is the number of pixels, and r_{jk} and r'_{jk} are the estimated values of the ratio of the reference members obtained by applying the linear spectral decomposition method and the measured values of these ratios, respectively.

An introduction to the study area

Gorgan gulf is located in the southeastern part of the Mazandaran sea in the Golestan Province. In fact, it has been developed because of the growth of the long and narrow prong of Miankaleh in the region. Due to the proximity of the shores of the Miankaleh peninsula to the sea, the connection of these coasts to the waves, and seawater level changes in the last few years, these coasts have been subject to changes in terms of morphology. Changes in the Caspian base level in coastal areas of the gulf have led to changes in the use and pattern of landuse in these areas and even the surrounding areas over time.
The gulf of Gorgan is about 400 km wide. As the maximum depth reaches 4 meters with respect to the sea level rise, it is shallow. The ecology of Gorgan gulf is affected by the Caspian Sea, the surrounding rivers and the Miankaleh peninsula. Therefore, it can be said that the Miankaleh peninsula and Gorgan gulf are two inseparable biological and geographical environments.
The Gorgan gulf and the Miankaleh peninsula have become a protected biological range. Nevertheless, the untimely overfishing, an increase in the importation of industrial, pastoralism

and agricultural from one hand and the environmental importance of mineral resources of the Gorgan gulf and a greater utilization of food resources for the country's increasing population on the other hand, justify the necessity of more attention and research on the properties of the Gorgan gulf and the Miankaleh peninsula. Figure 2 shows the geographic location of the study area.

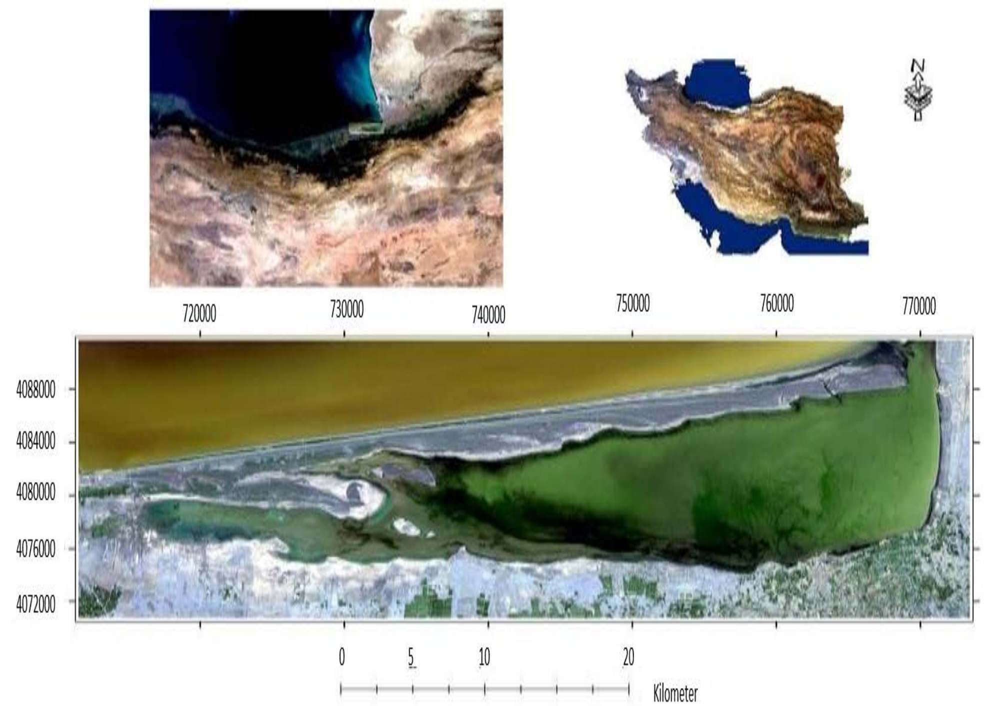

Figure 2. Geographic location of the studied area

Discussion

The research procedure, and instruments

Table 1. The characteristics of the data and information used in the study

Data	Source	Application
Sentinel 2 image	European space agency (ESA)	Classification and extraction of uses
Landsat 8image	The United States Geological Survey (USGS)	Classification and extraction of uses
25000 Maps	The Surveying Organization	Building blocks map
Communication lines	**Open Street Map**	Distance from roads and modeling of applied change
Topographic map	The Surveying Organization	Modeling use changes
Weather data	The Meteorological Organization	Meteorological information

The data and information characteristics used in the research were based on the calculations and procedures required to model the land-use changes in the studied area like the application of multitemporal remote sensing imagery, applying classification techniques, modeling of land-use change, and some spatial analysis functions in the GIS environment.

Other data used in this study were the global maps of 25,000, which were obtained by the country's surveying organization by interpreting the scale of scale 1: 20,000 .The location information of the Gorgan gulf area was a source of a **Open Street Map**. The topographic data was also used in the current investigation. The data and information specifications used in this study are listed in table 1.

The used software in this study included **ArcGIS**, **Excel**, **ENVI**, **Word**, and **Idrisi**. The procedure and process of the current research began after initial studies and acquaintance with literature, from receiving satellite imagery of **Landsat 8** and **Sentinel 2**. As indicated in earlier sections, these images were highly spatial resolution images. Compared to commercial images, however, these images were of a much lower capability to extract the land-use information, they were selected for this study because of their free access capability. After receiving the images of **Landsat 8** and **Sentinel 2** and in order to prepare them for applying classification patterns and finally extracting the information of land-use, the required properties were applied to them in the **ENVI** image processing software environment. In general, a relatively significant amount of time of this study was spent on the preparation and implementation of the corrections for their application in the future analyses. These preparations` stages included the execution of the image band layer stacking, the Geo-referencing, and the geometric and radiometric corrections, the cutting, the application of resolution enhancement filters, and the creation of color combinations. After completing the image preparation and preprocessing steps, the maximum likelihood classification algorithm was used as representative of parametric supervised classifiers on pre-processed image bands. The abovementioned algorithm was applied on both categories of **Landsat 5** and **Sentinel 2** which were taken in 1992 and 2017, respectively. The outputs from their application were land-use maps of 30 and 10 meters in the study area, which resulted from **Landsat8** and **Sentinel 2** image processing, respectively. To apply and evaluate the accuracy of these classification methods, sampling various land-uses and the detectable effects of images were needed. To this end, different color combinations from different arrangements of image bands in the **RGB** color space, **OSM** and **Google Earth** images, and **25000** reference images were used. Training and test data were classified into six and five different groups for **Landsat** and **Sentinel** images, respectively. In order to implement the classification algorithm, half of the sampled data were used. However, the other data were also used to evaluate the accuracy of the output land-use classes. After applying the MLC on the images, land-use maps were obtained after taking the images. To evaluate and verify the accuracy of the results and the outputs indicating the used classes position and level, the error matrix was set based on the test data taken in previous stages and the accuracy evaluation parameters were calculated separately for each uses and classification methods. After validating the results, the land-use map of Gorgan Gulf range and margin, including the “agricultural and horticultural”, “grassland”, “built-up”, “fallow and barren”, and “coastal” was prepared. These maps were used together with topographic information layers and pedestrian network of the study area as the entries of the LCM module were prepared. After modeling and detecting land-use changes of the study area, the parameters and quantities representing different aspects of changes in the 25-year period were measured and provided. These aspects consisted of the area and ratio of changes and transformations between land-use, net changes of each use and the probability matrix of conversion among land-uses for each separate future use. In the end, land-use changes and the effects of changes in the surface of Gorgan gulf were analyzed, including the transgression and regression of its coast in other changes of land use. The general steps of the study are shown in figure 3.

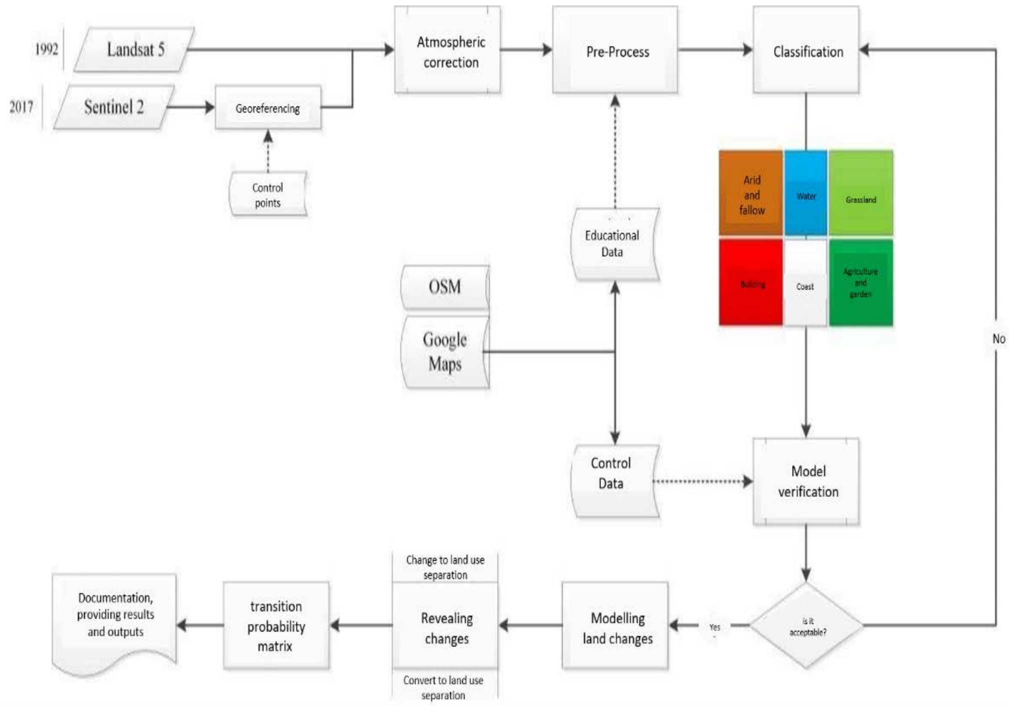

Figure 3: general steps of the study

Table 2. The characteristics of the images used in the study

Satellite	Number of bands	The date of the take	Spatial resolution (Meter (s))
Sentinel 2	12	08-08-2017	10, 20, and 50
Landsat5	11	14-08-1992	15 and 30

Image classification

Extracting the desired uses from satellite imagery requires the use of one of the classification methods on satellite images bands. In this study, the maximum likelihood classification technique was used. The use of these classification algorithms requires sampling from data that represent desired uses in the real space and their classes in the image space. Therefore, **25000** maps, **Google Earth services**, **OSM** and various color combinations of basic images were used to obtain reference samples. For this study, according to the purpose of the study, the capability and the date of taking the pictures of these data were grouped into six land-use classes for **Landsat** and **Sentinel** images. The aforementioned Use classes were "agricultural and horticultural", "grassland", "body of water", "built-up", "fallow and barren", and "coastal". The main criterion for the segregation of these lands was reflected by the meter at the time of the satellite transition from the study area. Therefore, in some cases such as fallow lands or agricultural/horticultural lands, although they were different in terms of land-use, they were both included in the same category in terms of the electromagnetic spectral reflection. Barren lands were bodies of lands without permanent and dense vegetation and water, which was largely the result of other changes in land-use and were not appropriate for cultivation. On the other hand, fallow lands were agricultural bodies of lands said to be prevented from cultivation for some reasons. In order to perform the classification of 50%, the samples were selected using random selection function in **ArcGIS** environment, and the rest were used to evaluate the accuracy of the classifiers. The total area covered by the training and test samples was **53.2845** and **55.6124**, respectively, for **Landsat** and **Sentinel** images. This was approximately

2.4 % of the total area of Gorgan, including the surrounding lands as the study area. In sampling the reference data, it was attempted that the quantity allocated to each used class, be tailored to the level covered by it in the study area. Figure 4 shows the position of the training and test samples in the study area.

In the maximum likelihood (the most similarity) method, for examining the spectral values and the statistical probability of correlation of a pixel with one of the sample groups, the variance matrix and mean vector was used, which defined the variance and correlation of spectral values. In the aforementioned method, the degree of membership of a pixel to each class could be estimated by multivariate normal distribution functions.

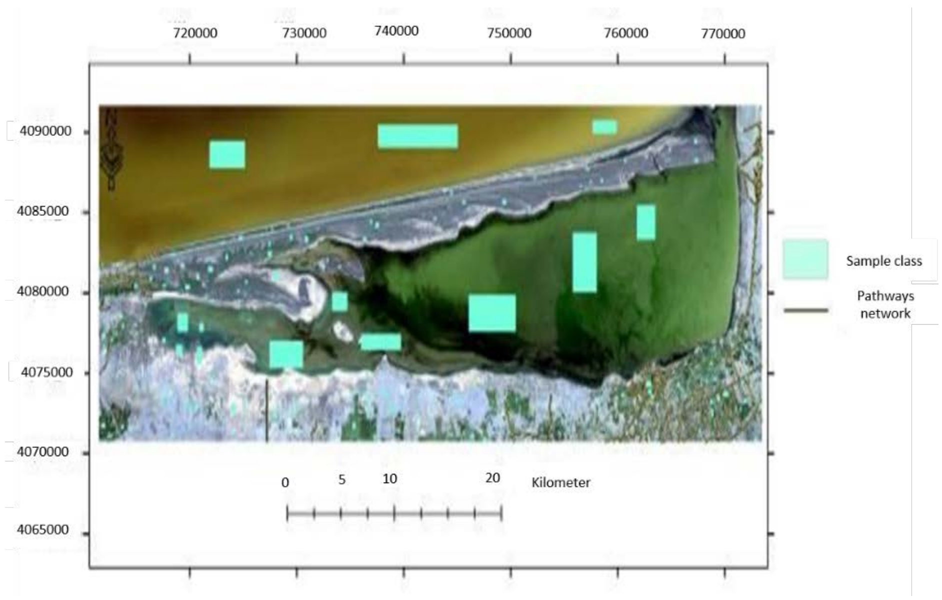

Figure 4: The spatial dispersion of the training and test samples

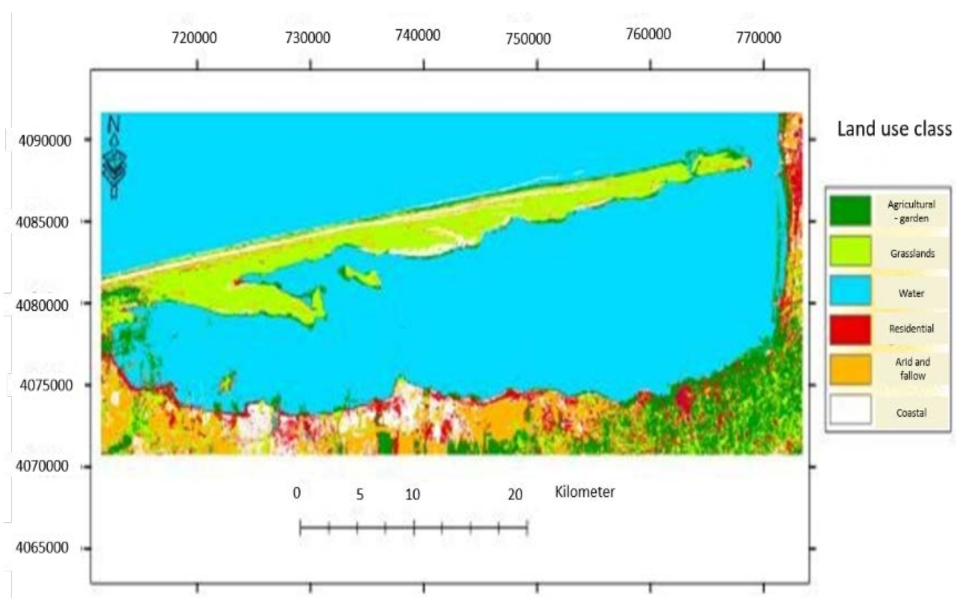

Figure 5: The land use map resulting from applying the maximum likelihood classifier on the **Landsat** image in 1992.

In this study, the maximum likelihood method was implemented on 4 bands of **Sentinel 2** and 6 bands of **Landsat**. The reason that only 4 **Sentinel** band images were used was that these bands had a **10** m spatial resolution, while other bands had **20** m and **60** m pixels. Because the objective was to produce maps with pixels of **10** m, the spectral information from other bands was inevitably ignored. On the other hand, the degree of correlation between some bands of **Sentinel 2** was particularly high in the red edge area of the electromagnetic spectrum which reduced the potential for extracting the information from them during the classification process. Figures **5** and **6** show the land-use maps resulting from the implementation of the maximum likelihood technique on the **Landsat** and **Sentinel** images, respectively.

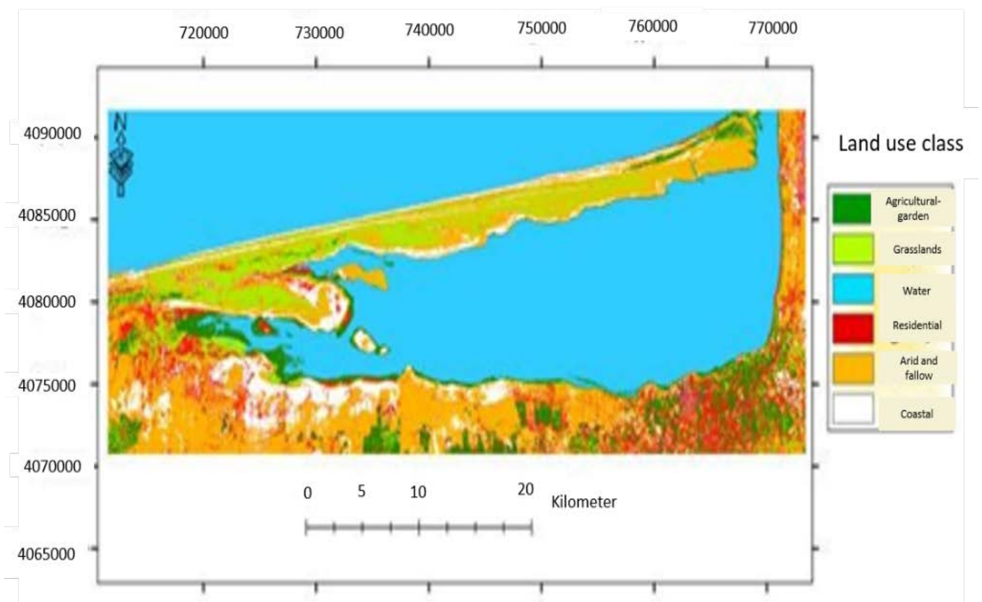

Figure 6: The land-use map of applying the maximum likelihood classifier on **Sentinel 2** images in **2017**

The evaluation of the image classification results

Table **3** shows the error matrix for the maximum likelihood classifier on **Sentinel 2** images. Due to the lack of access to reference data for the 1992 image survey, the results of the survey of land-use classes in **2017,** considering that a similar classifier has been employed in both cases, have been extended to the results of **Landsat** image classification in **1992**. The values of the overall accuracy and kappa coefficient are shown in table **4**. In table **5**, the producer's accuracy values, user's accuracy, and omission/commission errors are added to the breakdown of Use classes.

Table 3. The error matrix for the maximum likelihood classifier on the **Sentinel 2** image.

Use class	accuracy parameters					
	Agricultural and horticultural	Grassland	Body of water	Built-up	Coastal	fallow and barren
Agricultural and horticultural	4539	1	4	8	166	9
Grassland	0	737	0	18	2	5
Body of water	13	4	661	0	0	19
Built-up	2	0.108	0	1061	0	11
Coastal	50	0	0	0	2060	13

fallow and barren	**5**	**34**	**152**	**37**	**92**	**4037**
				Sentinel 2		**Classified image**
				Kappa coefficient	Total accuracy	Accuracy estimation statistic
				0.94562	0.94562	

Table 4. General accuracy values and kappa coefficient for the maximum likelihood classifier

Image	Use class	accuracy parameters			
		User's accuracy	Commission error	User's accuracy	Omission error
Landsat5	Agricultural and horticultural	0.8178	0.1822	0.8804	**0.0156**
	Grassland	0.7888	0.2112	0.9844	**0.0156**
	Body of water	0.9602	0.0398	0.9848	0.015
	Built-up	0.8892	0.1108	0.9558	0.0442
	fallow and barren	0.6791	0.3209	0.9189	0.0811
	Coastal	0.973	0.9972	0.9972	0.0028

The values of the accuracy of the classification exerted on the **Sentinel 2** image were indicative of an acceptable accuracy of the maximum likelihood classifier, so both the overall accuracy and kappa coefficient confirmed this issue. Meanwhile, the accuracy of the coastal classes and water bodies accuracy showed the highest accuracy among the estimated Use classes, while other estimated classes were also of an acceptable accuracy.

Detection of the changes in land use

After classification of images in two time groups of **1992** and **2017**, and the confirmation of its results, the modeling stage and the detection of land-use changes took place. In general, the detection algorithms in remote sensing are different in terms of goals and complexity. In this paper, the **LCM** module in the **Idrisi selva** software was used (Figure **7**). The main inputs of this module were the classified images from the beginning and end of the time period between which the land-use changes had to be investigated. In addition, other inputs such as the Digital Elevation Model (**DEM**) and pedestrian network of the study area were used to model and estimate land-use changes in the period of 25 years. The outputs from the execution of this modeler were made in maps, diagrams, and graphic figures and tables that are given as follows.

Figures 7 to 12 show the maps of land-use surface change direction in three nodes of area decrease, area increase, and surface stability. Figures 13 and 14 show the increase and decrease in surface to the separation of land-uses in two relative nodes, with respect to the initial and absolute area. Table 5 also shows the values of the increase, decrease, and the net surface change to the separation of the types of identified land-uses. In general, the first point related to the estimated land-use changes was the 21 % reduction in the area of Gorgan gulf and its surroundings. Of course, the small increase in this area was significant in comparison to this decrease, so that the bodies of water of the studied area which was mainly the gulf of Gorgan, has been reduced by more than 150 KM^2 over the last 25 years. On the other hand, the regression of the gulf of Gorgan in the last three decades has been the source of changes in other land-uses. So that fallow and barren land-uses have experienced a + 150 km^2 increase and a relative net increase of 70 %. Hence the most brilliant land-use change had been marked. In addition reducing the use of water bodies, agricultural/horticultural lands, and grasslands also experienced a significant reduction in the surface area during these 25 years. On the other hand, except for fallow and barren lands, the coastal and built-up uses have had a significant increase in their area.

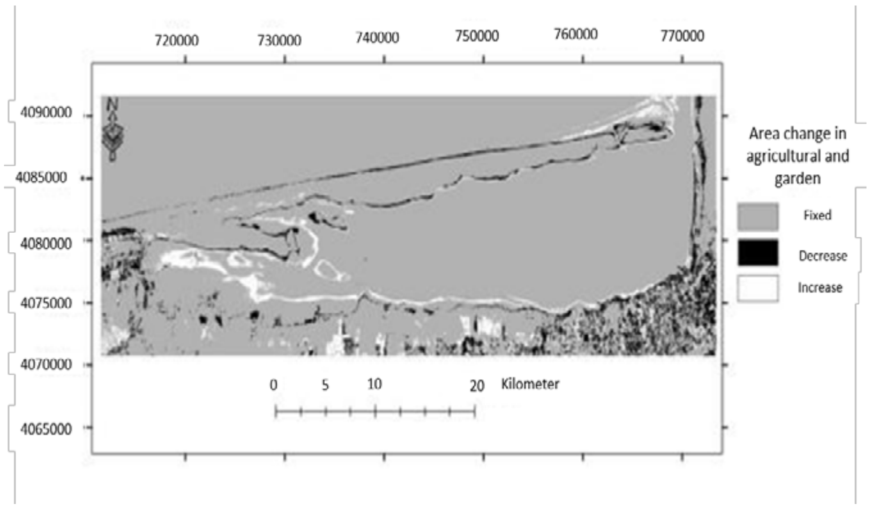

Figure 7: "Agricultural and horticultural' land-use change direction map

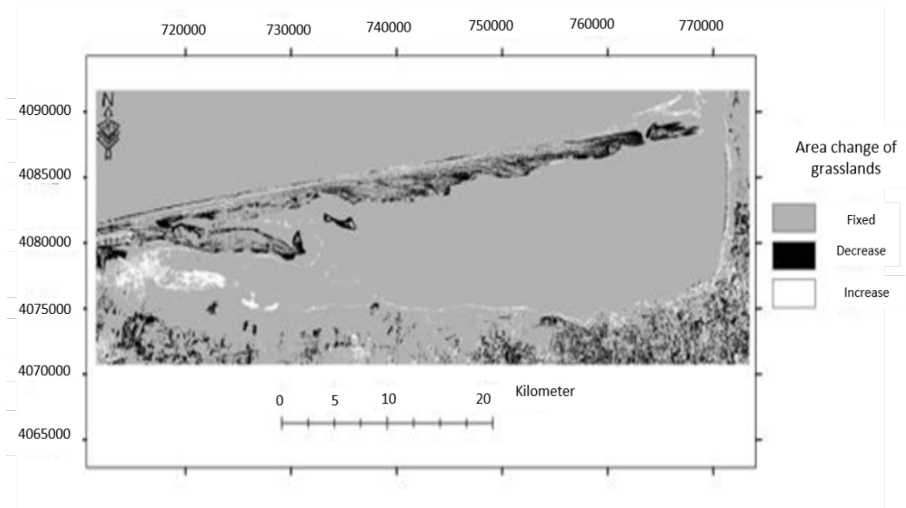

Figure 8: "Grassland' land-use change direction map.

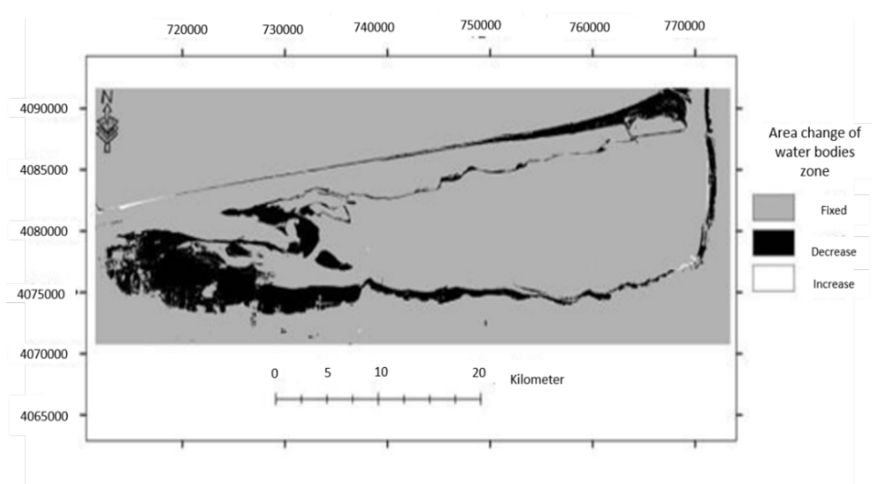

Figure 9: "Water bodies' land-use change direction map.

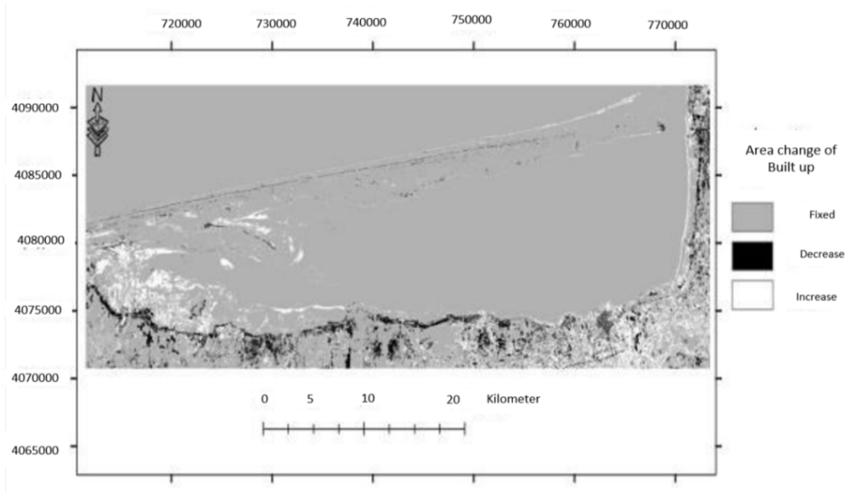

Figure 10: “Built-up’ land-use change direction map.

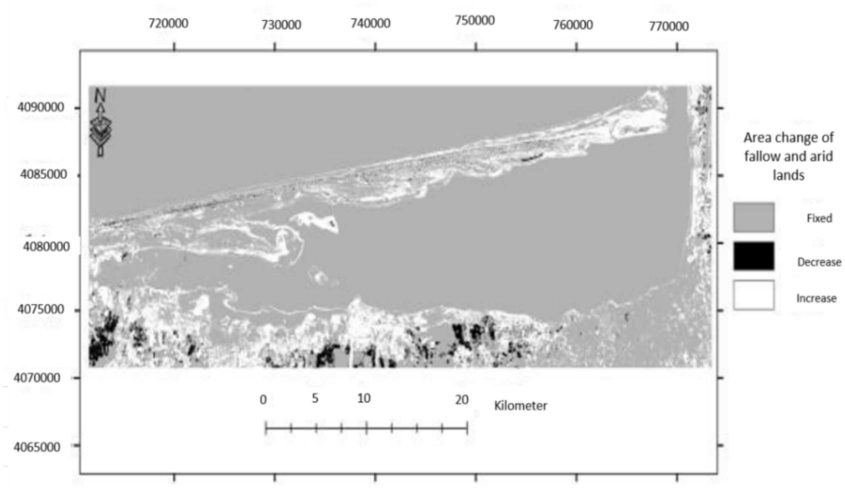

Figure 11: “Fallow and barren land-use change direction map.

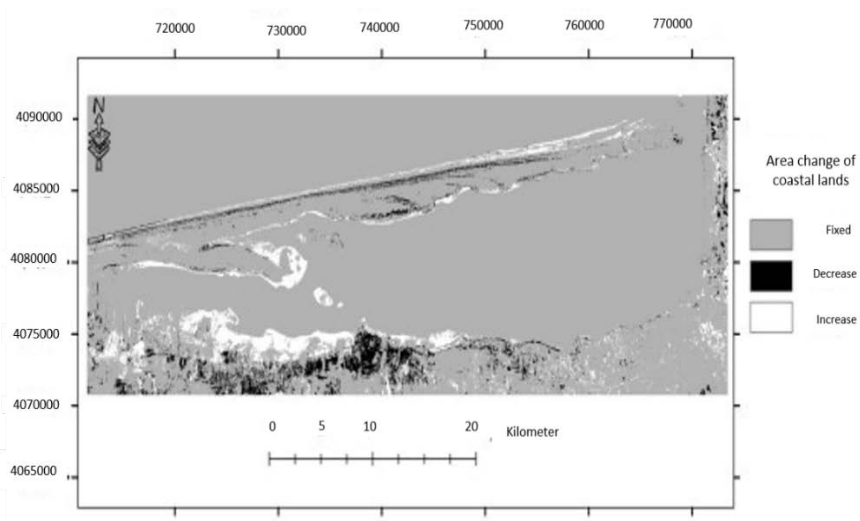

Figure 12: Direction map of ‘coastal’ land-use change.

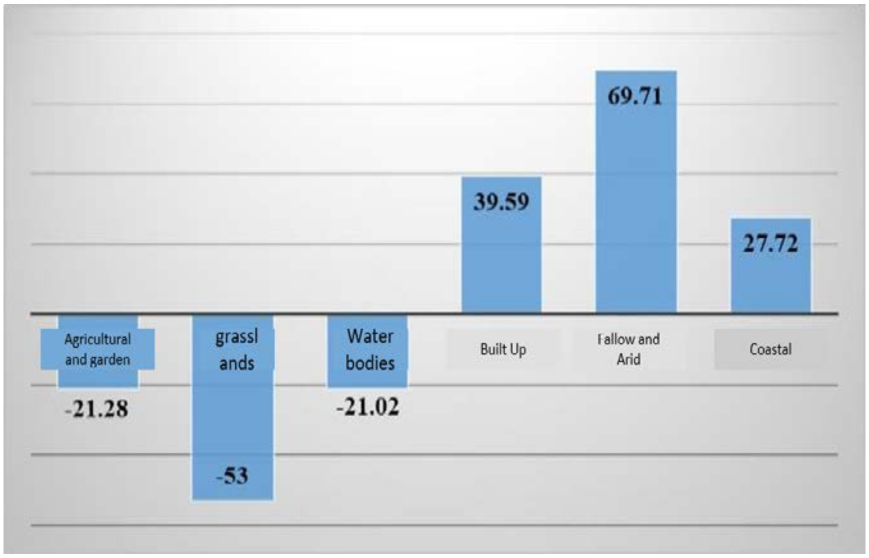

Figure 13: The percentage and the direction of the land-use area net changing to an initial area

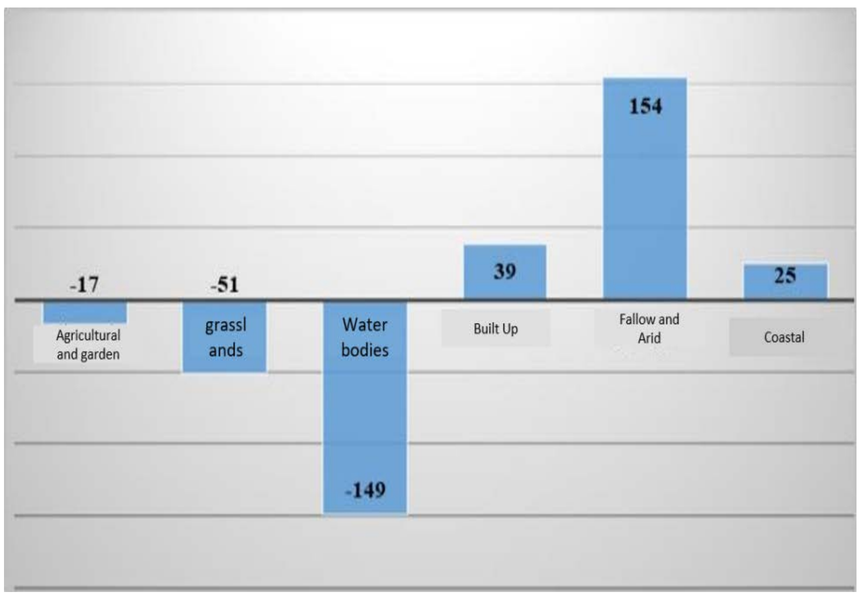

Figure 14: The land-use area net change (km^2).

Figures 15 to 20 showed the identified land-use surface changes due to changes in the area of other uses in this period of 25 years. In these figures, the positive values in each rectangular graph showed the area added to the desired land-use in km^2 and negative values indicated a decrease in the area of the desired land-use and converting it to the determined land-uses. The salient features mentioned in this study indicated that all values were negative for water bodies and all values were positive for fallow land-uses. That is, all changes have been directed to the creation of other uses for water bodies, reflected from the reduction of the 150 km^2 in the level of the gulf of Gorgan at the time period of study. While the total positive values for diagram **4-18** showed that the sheer changes of other uses have been directed to this particular land-use. Most of the area increase by water bodies has been extended to beaches, while the largest increase for fallow and barren lands was from grasslands.

Table 5: The incremental (increasing) and decreasing change in the land-use area (km²)

Land-use class	Surface change (km2)		Net surface change (km2)
Agricultural and horticultural	Increase	56.13	-16.72
	Decrease	72.85	
Grassland	Increase	40.14	-51.48
	Decrease	91.62	
Body of water	Increase	1.55	-149.20
	Decrease	150.75	
Built-up	Increase	82.05	38.59
	Decrease	43.46	
Fallow and barren	Increase	177.56	154.11
	Decrease	23.44	
Coastal	Increase	70.29	24.70
	Decrease	45.59	

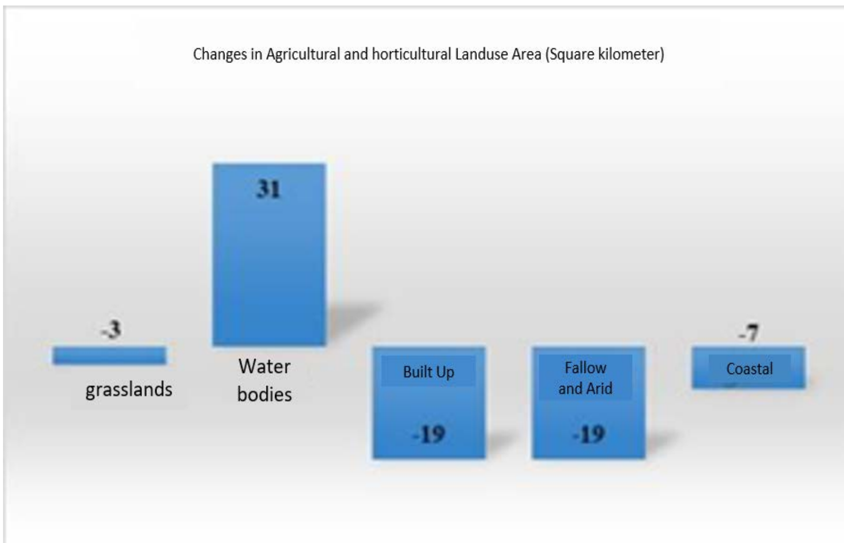

Figure 15: The "agricultural and horticultural" land-use surface change caused by other land-use changes

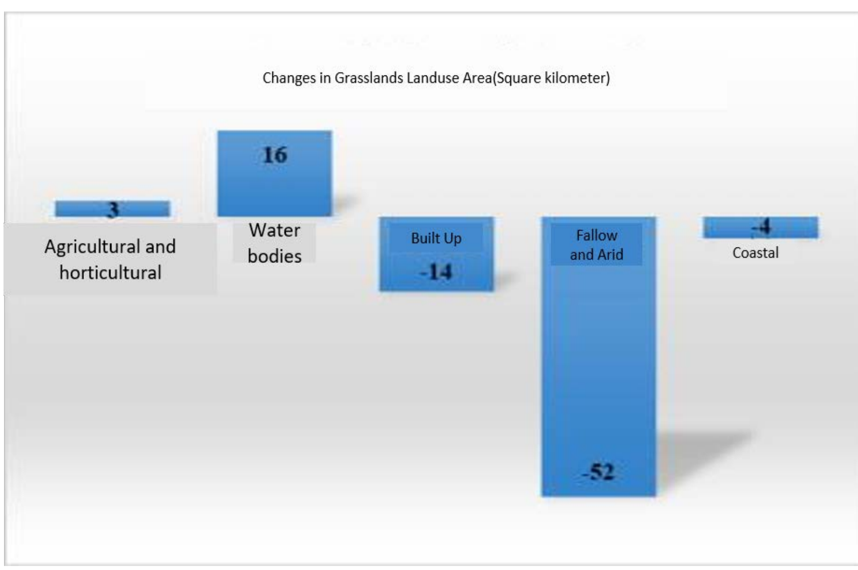

Figure 16: "grassland" land-use surface change caused by other land-use changes (km²).

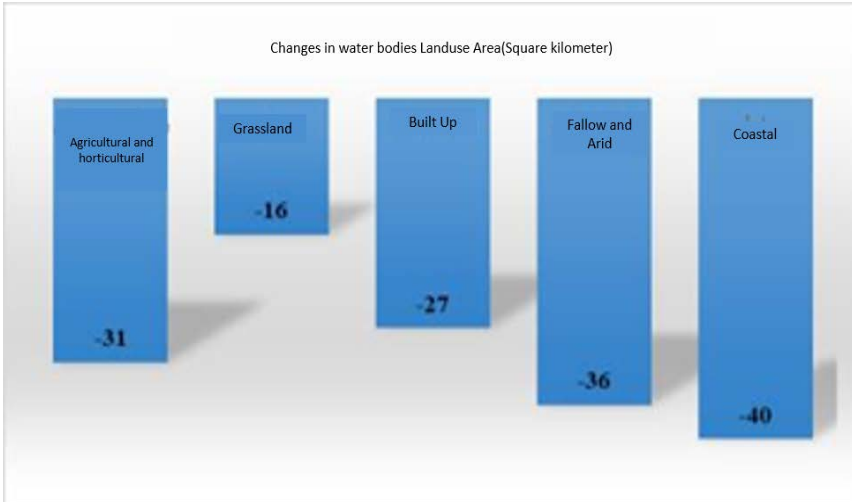

Figure 17: The "water bodies" land-use surface change caused by other land-use changes

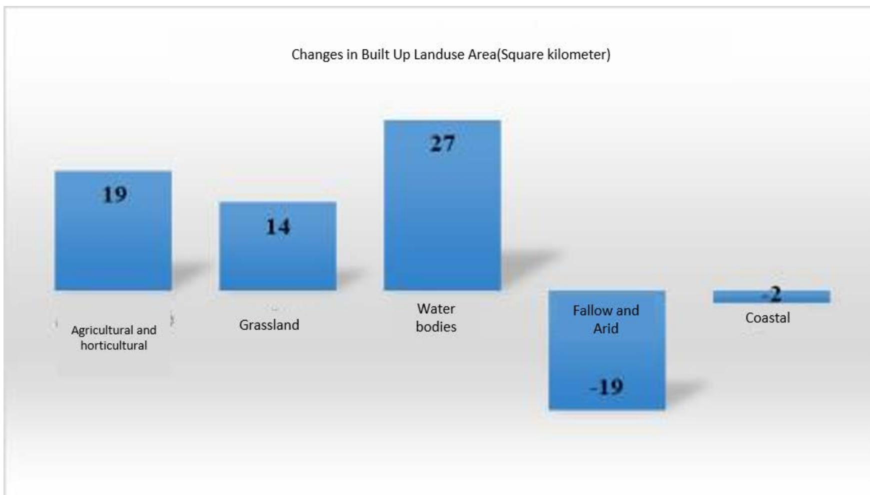

Figure 18: "built-up" land-use surface change caused by other land-use changes (km^2).

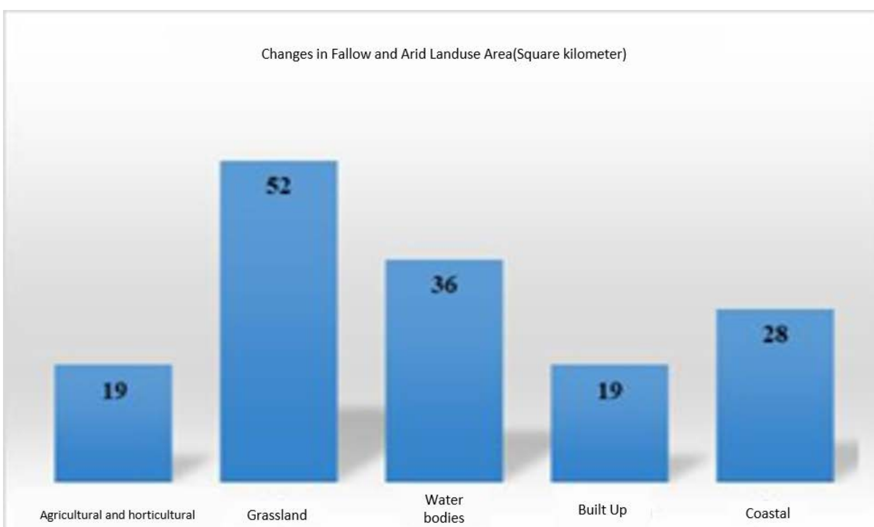

Figure 19: The "fallow and barren" land-use surface change caused by other land-use changes (km^2).

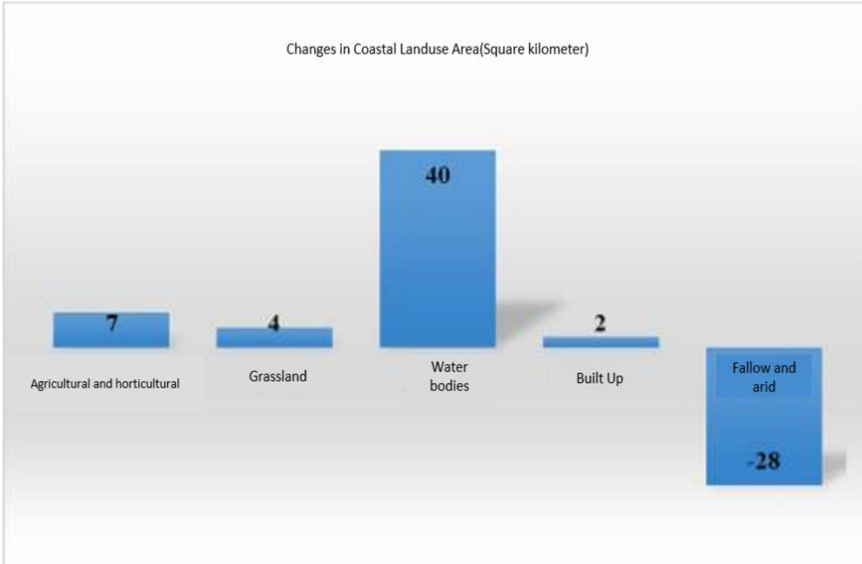

Figure 20: The “coastal” land-use surface change caused by other land-use changes (km^2).

Figure 21 showed the land stability map. The stability refers to the areas that are immune from the change in these two temporal nodes. **Figure 22** presented an area immune from the land-use changes to the separation of land use. Although water bodies have shown the most stability at the surface, it should not be neglected that the biggest part of the surface has been assigned to this use, so that the degree of change in other land-uses was much lower than the land area stability of water bodies. **Figures 23 to 28** showed the maps of the land-use conversion to the desired land-use.

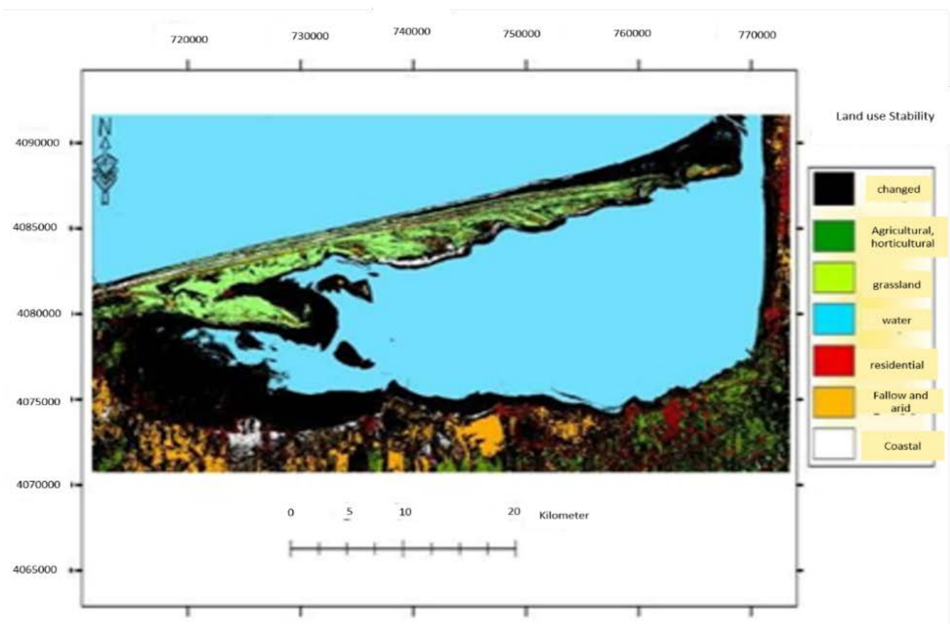

Figure 21: The land-use stability map

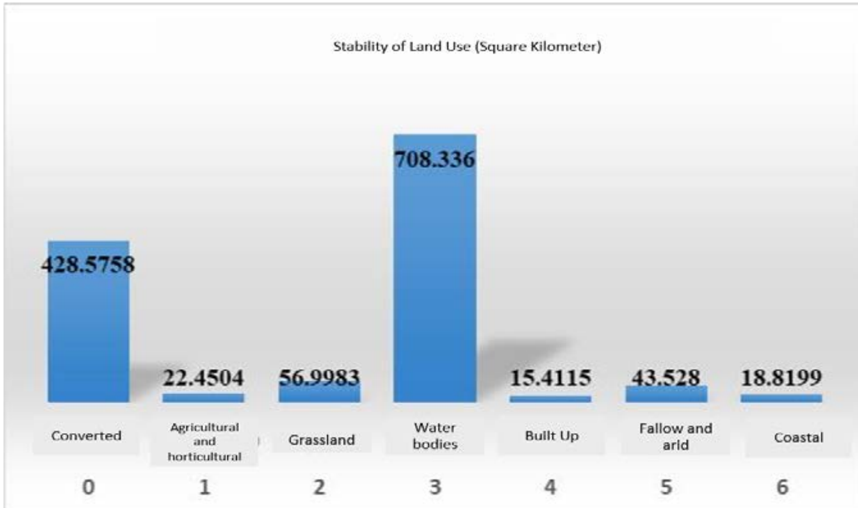

Figure 22: The map of land-use stability values to the separation of land type

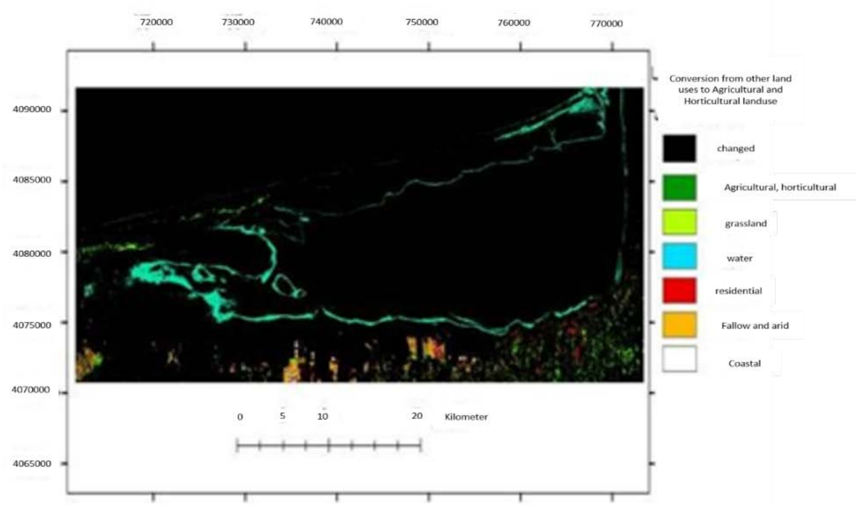

Figure 23: The map of land-use conversion to the “agricultural and coastal” land-use

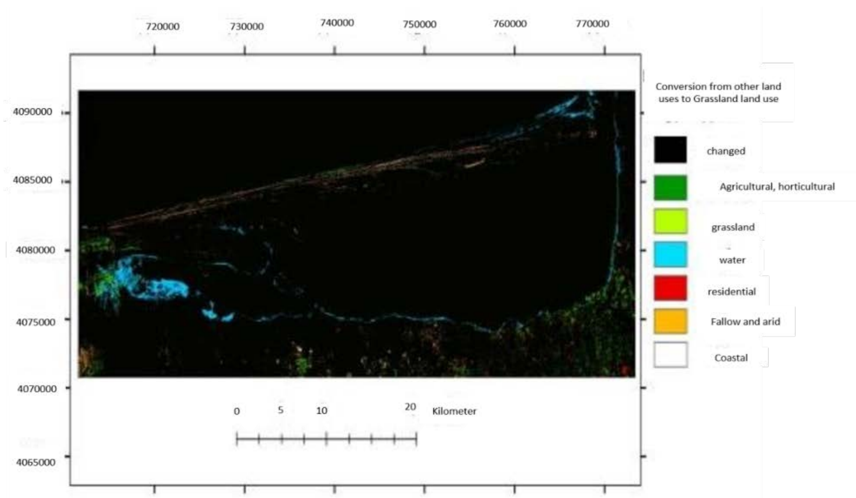

Figure 24: The map of land-use conversion to the “grassland” land-use

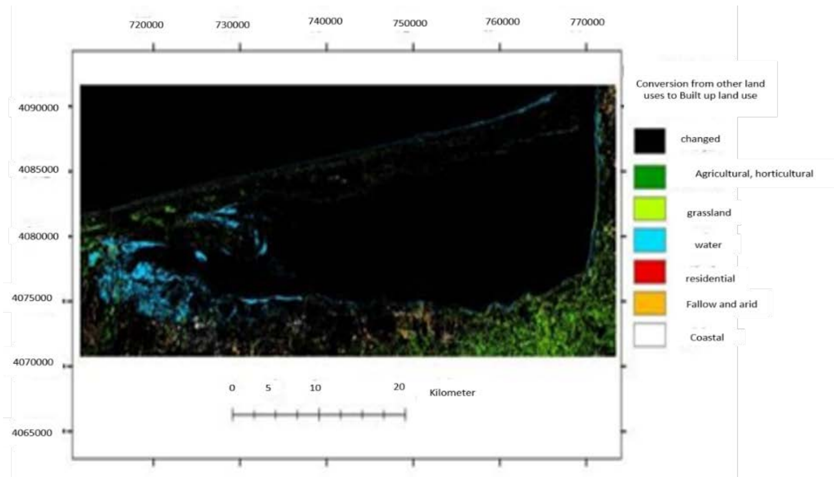

Figure 25: The map of land-use conversion to the “water bodies” land-use

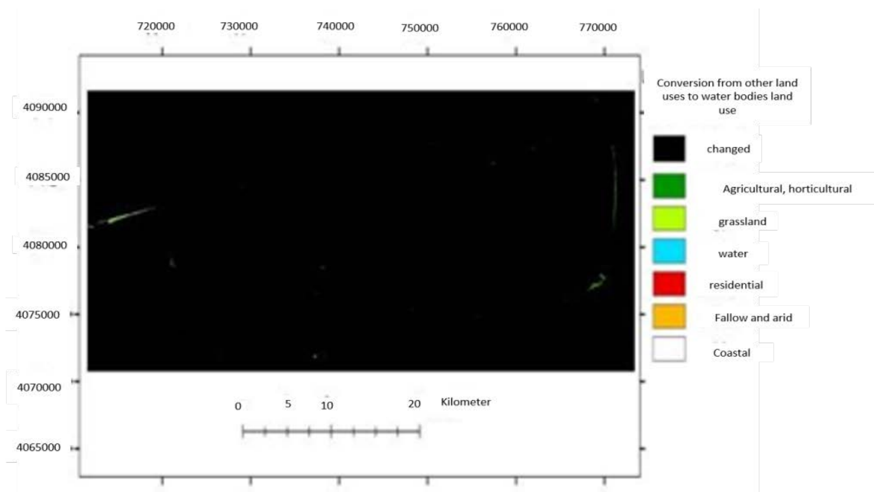

Figure 26: The map of land-use conversion to the “water bodies” land-use

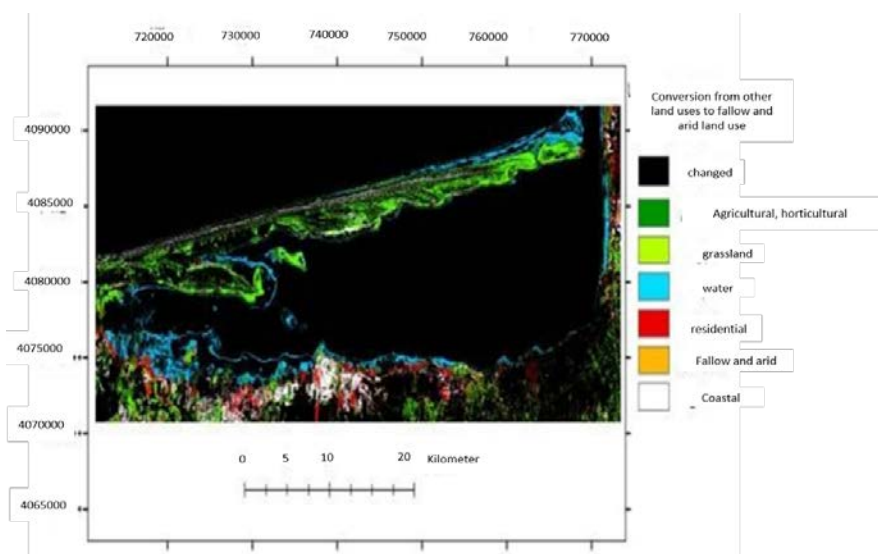

Figure 27: The map of land-use conversion to the “fallow and barren” land-use

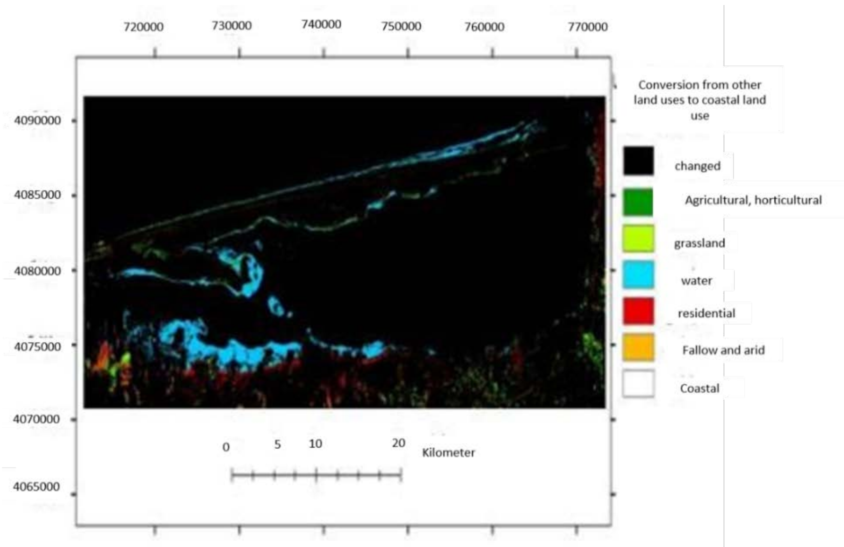

Figure 28: The map of land-use conversion to the “coastal” land-use

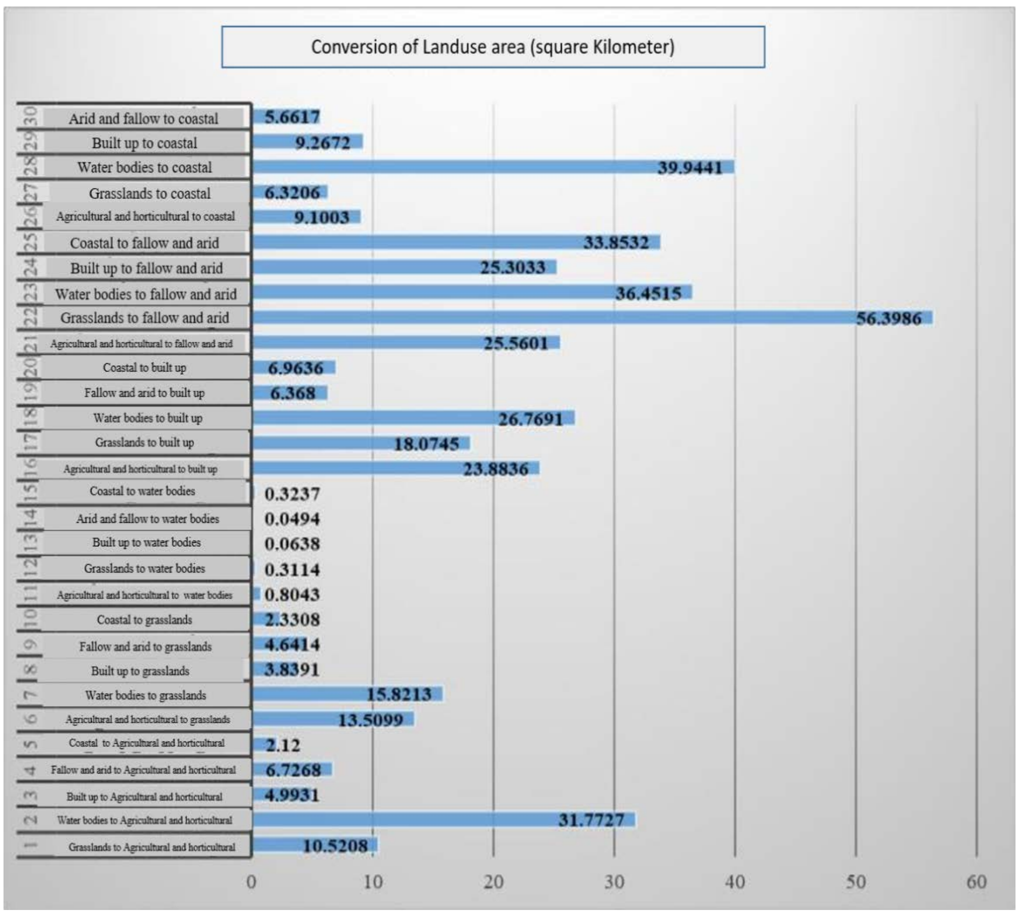

Figure 29: The map of land-use conversion to the “coastal” land-use

Figure 29 showed the conversion diagram among land-uses to separate the converted surface from one land-use to another. This figure was somehow complementary and confirmatory to other findings mentioned above. The maximum converted surface was related to the change from rangeland (grassland) land-use to the fallow and barren land-use. While the minimum converted area of land was related to the change from fallow and barren land-use to water bodies land-use.

Results and findings for the detection of land-use changes

The process of this study was implemented in three general steps. In the first step, the required data, mainly satellite imagery, were received. The second step, i.e. the classification of images for land-use detection, was carried out after applying the necessary pre-processing and preparations. In this step, land-use maps were modeled in two temporal nodes of **1992** and **2017** and after the verification of accuracy, the aforementioned maps were entered into **Idrisi** software environment as the inputs of land-use changes. As the most important stage in the study, the land-use change detection process demonstrated many aspects of land-use change over the last three decades. The maximum reduction was associated with the estimated surface for water bodies, which was mainly covered by the Gorgan gulf waters. While the most increase in the area was associated with the fallow and barren lands, other land-uses had also undergone changes in terms of their surface between the two sides of this spectrum. Most of the changes and conversions between the first two land-uses were related to the conversion of grassland use to fallow and barren uses, and then it has been related to the conversion of water bodies' use to coastal lands use. In terms of stability, the highest stability was occurred in the area of water bodies, which was probably due to the lack of change in these zones in the first place and especially in the gulf of Gorgan. However, it was actually due to the highly-covered surface by this land-use compared to other lands, which, despite the reduced 15,000 hectares over 25 years, its fixed surface was higher than unchanged zones of other areas. Changes in land-use could be divided into two categories: first, the surface of land-uses such as the range of Gorgan gulf, agricultural and horticultural lands, and grassland fields were reduced. In general, these three land-uses were similar in terms of function and effect on the environment, human beings, and other organisms, living and non-living. Certainly, the main need for green lands such as ranches and rangelands was water demand. Surely, the reduction of water surface area will have a negative impact on the mentioned land area. The second category of land-use changes which undergone an increase in surface area was related to fallow and barren lands, coastal areas and built-up uses. These three uses were placed in one category in terms of their relation with the environment and human beings, and in some way, their level of pure increase was due to the function of human activities, especially in the case of built-up lands. Problems such as population growth, increased excessive exploitation of forest resources and grasslands, climate change, drought, and immethodical construction that affect the gaunt figure of the first category, have led to an increase in second-category uses, mainly representing environmental degradation.

One of most important and practical outputs from the implementation of LCM implementation was the probability matrix of conversion among land-uses in pairs (Table 6). The numbers on the main diagonal of the probability matrix represented the possibility of converting the two identical uses that were expected to have the highest values. On the other hand, however, other entries showed probability values between dissimilar uses. Table 6 which showed the mentioned matrix according to the trend of changes estimated during a 25-year period for 2030, suggested that with the persistence of this situation, the process of gulf of Gorgan regression would continue, because there is minimum likelihood for return from other uses to water bodies. An important point that was highlighted in the matrix values was that in the case of built-out and coastal uses, the probability values of converting to dissimilar uses was higher than the values of the coastal land-use stability. The ratio of coastal land conversion rate to barren lands, for instance, was higher than the stability of the coastal lands. The built-up land conversion rate to barren lands was also higher than the stability in built-up land-uses by 2030.

Table 6: the probability matrix of land-use changes to one another in 2030

Use class	Agricultural and horticultural	Grassland	Body of water	Built-up	fallow and barren	Coastal
Agricultural and horticultural	0.329	0.5214	0.0072	0.3004	0.1386	0.755
Grassland	0.054	0.0097	0.0012	0.1093	0.3023	0.0121
Body of water	0.03	0.0482	0.9027	0.0173	0.0052	0.035
Built-up	0.0078	0.0503	0.0	0.3488	0.3578	0.1718
fallow and barren	0.096	0.0126	0.0	0.0689	0.7171	0.0677
Coastal	0.0	0.5214	0.0042	0.0987	0.4854	0.3991

The impact of the regression of Gorgan gulf on land use surface

The surface of Gorgan gulf was covered by water bodies use in classification maps. As the detection of land-use changes in the period of 1992 to 2017 showed, the surface of Gorgan gulf reduced by 150 km; in other words, the consequence of what has passed over the gulf of Gorgan over the last three decades has been seen as regression. In order to observe the effects of this regression on the surface covered by other uses from land-use conversion maps, specifically convertions of water bodies to other uses is used. These values are shown in **Figure 29**. They are shown in Table 7 for further convenience. In general, coastal and barren uses have captured more than half of the converted surface of the Gorgan gulf during the study period. While agricultural and horticultural, built-up, and grassland uses came next. An increase in agricultural and horticultural use surfaces due to a decrease in the Gorgan gulf area cannot be considered undesirable at least in the short term. Obviously, the increase in the surface of the coastal saline land area indicated the full effects of immethodical operation and improper management of human beings from water and terrestrial resources and continuous drought in the study area. Regional planning and macro-scale management measures can lead to a modification of natural and climate effects. While not only has this been observed, but also based on the evidences being studied, mismanagements and unwanted adverse affected the climate.

Table 7: The increased area of land resulting from the reduction of the Gorgan gulf surface

Shaped use	Converted area (km^2)
Agricultural and horticultural	**31.17**
Grassland	**15.82**
Built-up	**26.76**
Fallow and barren	**36.45**
Coastal	**39.94**

Conclusion

With the development of urban and rural communities, increasing population and the excessive use of human beings from terrestrial resources, and detriment to the environment and ecosystem, an increased attention of human beings to the land and its limited resources in the direction of sustainable development have been taken into consideration to prevent from damaging the land and its limited resources. Land-use and land cover change over time, natural and human factors as well, caused this change and conversions. In this thesis the surface changes of the main land-uses of Gorgan gulf were identified and estimated. The main stages of the study were implemented in three sections. In the first step, the remote sensing satellite imagery was received in two times in 1992 and

2017 and the data required were received from the required resources. After applying the necessary pre-processing and preparations such as the application of atmospheric corrections, the next stage was introduced, i.e., the classification of images for land-use detection of the lands of the study area. The satellite images included the **Landsat5** reflective bands in the visible range, near and middle infrared taken in **1992** and visible and infrared bands near **Sentinel 2** in the **2017**. In this stage, land use maps have been modeled in two temporal nodes **1992** and **2017** by applying the maximum likelihood classifier and after verifying the accuracy, as input to the LCM module, land-use changes entered into the **Idrisi** software. The uses that were estimated and extracted in the current study were based on the purpose and scale of the study, the capability of satellite images, and the natural state of the study range, including six uses: "agricultural and horticultural", "grassland", "body of water", "fallow and barren", and "coastal". Other inputs of the **LCM** module, in addition to the classified images, included a digital elevation model with pixel dimensions similar to the land-use maps and the pedestrian network map of the study area. The process of the land-use change detection as the most important step in the study revealed many land-use changes over the last three decades, primarily based on comparing uses in pairs in two temporal nodes and other influencing parameters in the process of surface change. The findings and results of the study are mentioned later: the maximum reduction of the estimated surface for water bodies was the area occupied by the Gorgan gulf. The most increase in the area was estimated to be for fallow and barren lands, other uses were located between the two ends. The highest level of conversion between the two uses has been assigned to grassland use conversions to fallow and barren lands the conversion of water bodies to coastal lands. In terms of stability or invariability of lands, the highest stability was for the surface of water bodies, which was due to the highly-covered surface by this use in comparison to other lands, so that despite a 1500 km decrease in water surface over three decades, the amount of areas immune from its changing have been more than the unchanged areas. In water bodies, all changes have moved towards making another use, which has mainly reflected the 150 km2 reduction in the surface of Gorgan gulf in the timeframe. While net changes are estimated to move from other uses to fallow and barren use. The highest increase in land has been from water surface to create coastal lands, while the highest increase for fallow and barren lands have been applied by grassland (pasture land). In terms of quality, the land-use surface changes have been divided into two categories: first, Gorgan gulf water bodies uses, agricultural and horticultural lands, grasslands whose area have reduced, and the second category composed of fallow and barren lands, coastal lands, and built-up use whose area has undergone a net increase. The categorization of these changes was carried out not in terms of the increase or decrease in their surface, but due to a close link to the environment and its non-renewable resources. The first category of changes indicated a negative process of environmental transformations mainly caused by the two-sided impact of regional and natural factors as well as the crazy activities of human beings. While the second category had been the consequences of the changes and the functions resulted from the second category. Definitely, a higher area under cultivation of agricultural and horticultural lands, forests, grasslands, and water bodies, would indicate a more appropriate situation and more sustainable functioning of the habitat and numerous surrounding ecosystems. This study has highlighted the coastal ecosystem, and in the same way the increase in the area of fallow and barren lands and even coastal and saline areas are not somehow desired by a dynamic and healthy environment. One of the most important findings resulting from the modeling of land-use changes is the probability matrix of converting land-uses to one another in pairs. In this study, the mentioned matrix was calculated on the basis of the estimated variation over a **25**-year period and has been estimated for **2030**. The values of the matrix entries conversion rate indicated that as the current situation continued, the regression procedure in the Gorgan gulf also continued. In general, what this study clarified was that it had only been confronted with the regression of the gulf of Gorgan, so that the minimum likelihood was to return from other uses to water bodies. Moreover, the highest rates were estimated for converting to fallow and barren land use. The results of this study could be provided to regional planners at a macro level to minimize the impact of these undesirable changes in short term and long term. It should not be neglected that the natural environment and its valuable resources were not only those of the present generation, but the generations after us would have the right to use them. To prevent the emergence of crises and natural disasters caused by profiteering and mismanagement by some people, it is necessary to prefer the collective and national interests over personal interests. There was a significant correlation between the effects of the transgression and the regression occurring in the specified period and land-use changes of the Gorgan gulf. The main aspect of this study was to investigate the capabilities of satellite images in modeling and detection of land-use changes in the gulf of Gorgan. Therefore, two multispectral remote sensing satellite images were used to model the land-use changes. According to the study area and capability of these images and based on existing standards, which showed the relation between the scale of maps, spatial resolution power and satellite images, and the details of extracted land use, the estimation of areas covered by six major lands-uses were put to practice. These land-uses were: "agricultural and horticultural", "grassland", "water bodies", "built-up lands", "coastal lands", and "fallow and barren lands". After extraction of the mentioned land-uses by applying the maximum likelihood on the prepared bands of satellite images, the accuracy of them was evaluated; the values of the overall accuracy and the kappa coefficient indicated the accuracy of the implemented pattern on the images. As being inferred from the study's findings, the gulf of Gorgan has been remarkably regressed in the last 25 years, and there was no transgression at all. On the other hand, according to chapter 4 and the results of the modeling of the land-use changes, there was a close connection between this remarkable decrease in the area of Gorgan gulf, and many other uses. For instance, the changes in the surface of Gorgan gulf have led to an increase in barren and saline coastal lands, whereas wild activities of human beings have resulted in the reduction of grasslands as well as agricultural and horticultural lands.

References

1. Ahmed, A., Drake, F., Nawaz, R. and Woulds, C. (2017). Where is the coast? Monitoring coastal land dynamics in Bangladesh: An integrated management approach using GIS and remote sensing techniques. Ocean & Coastal Management.
2. Kaliraj, S., Chandrasekhar, N., Ramachandran, K.K., Srinivas, Y. and Saravanan, S., 2017. Coastal land use and land cover change and transformations of Kanyakumari coast, India using remote sensing and GIS. The Egyptian Journal of Remote Sensing and Space Science.
3. Khoi, d.d., y., Murayama .2010. Forecasting areas vulnerable to forest Conversion in the Tam Dao national park region, Vietnam. Remote sensing 2 (5), 1249–1272.
4. Powell, R. L., Roberts, D. A., Dennison, P. E., & Hess, L. L. 2007. Sub-pixel mapping of urban land cover using multiple endmember spectral mixture analysis: Manaus, Brazil. Remote Sensing of Environment, 106(2), 253-267.