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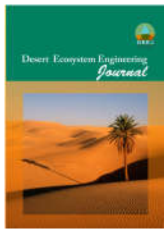


# Investigating the effects of human activities and climate change on land degradation and Jazmurian wetland dryness

**Saeed Barkhori[1], Elham Rafiei Sardooi[2]*, Hamed Eskandari Damaneh[3], Hadi Eskandari Damaneh[4], Farzaneh Ghaderi Nasab[5]**

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**Abstract**

Adopting appropriate management practices and preventing the constant destructive factors involved in such practices requires the protection and monitoring of wetlands. On the other hand, land use and climate change play an important role in the degradation of wetlands. Therefore, this study sought to assess Jazmurian wetland conditions during the pre-and post-dam construction periods and under different climate change scenarios, taking into account land use and climate change as two significant relevant factors. To this end, Landsat images collected from TM 1991, ETM + 2008, and OLI 2021 sensors were used to investigate the trends of land use changes. Finally, predictive land use maps were prepared for 2040 using the Land Change Modeler (LCM). Moreover, the changes in minimum and maximum temperature and precipitation rates were both investigated in the past and predicted for the future using different climate change scenarios and the Statistical Downscaling Model (SDSM).

The results of the land use investigation revealed that the area of wetland lake has decreased by 1611.45 $km^2$ from 1991 to 2021 and that the trend of land use changes in the future is considerable, leading to an increase in the area of agricultural lands and salt lands, and thus to complete wetland dryness. Moreover, it was found that the average annual precipitation rate had a decreasing trend in the past and that it will decrease in the future compared to the base period. On the other hand, the results of minimum and maximum temperature rate analysis indicated an increasing trend by 3 and 2.56 °C under the RCP 8.5, respectively, compared to the base period. Therefore, the reduced precipitation and increased temperature in the past and future, and the construction of the Jiroft dam can be considered as factors causing a decrease in the wetland area and its water supply, and changes in the wetland's surrounding ecosystems.

**Keywords:** Precipitation, Temperature, Dam construction, Land Degradation, Southeastern Iran.

1. Assistant Professor, Department of Ecological Engineering, Faculty of Natural Resources, University of Jiroft, Kerman, Jiroft, Iran

2. Associate Professor, Department of Ecological Engineering, Faculty of Natural Resources, University of Jiroft, Kerman, Jiroft, Iran; Corresponding Author: ellrafiei@ujiroft.ac.ir

3 Post-doctoral fellowship of Combating Desertification, Department of Arid and Mountainous Regions Reclamation, Faculty of Natural Resources, University of Tehran, Karaj, Iran

4 Post-doctoral fellowship of Combating Desertification, Department of Arid and Mountainous Regions Reclamation, Faculty of Natural Resources, University of Tehran, Karaj, Iran

5 Water Resources Engineer at Kerman Regional Water Company. PhD in Water Science and Engineering Shahid Bahonar University of Kerman, Kerman, Iran

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## 1. Introduction

Wetland has been defined and interpreted variously by different scholars and entities worldwide. For instance, the Ramsar Convention on Wetlands of International Importance defines wetlands as regions of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with static or flowing, fresh, brackish or salt water, including areas of marine water whose depth at low tide does not exceed six meters (Suman, 2019). The wetlands are influenced by any positive or negative influence of human activities as they are located in the outlet of watersheds. In other words, wetlands reflect human performance in watersheds (Maleki et al. 2019).

Considering the variety and complexity of human activities at the watershed scale, it seems impossible to clearly identify the contribution of each such activity to the conditions of wetlands (Azareh et al. 2021). therefore, planning for the conservation and development of wetlands requires monitoring their changes over time. Moreover, evaluation of the trends in land use change serves as a process that leads to a better understanding of the interactions involved between humans and the environment, being of great importance in the case of wetlands due to their high environmental susceptibility threshold (Ozesmi and Baur, 2002).

Remote sensing is a new effective technique for monitoring land use changes around wetlands (Azimi Sardari *et al*. 2019, Ansari & Golabi, 2019; Hu *et al*. 2020; Kouassi *et al*. 2021). In this regard, several studies have been carried out at global and national scales on the monitoring of land use changes around wetlands (Munishi & Jewitt, 2019; Malik & Rai, 2019; Lamsal *et al*., 2019, Gideon & Bernard,2018).

Apart from land use change which plays a major role in changing the wetland ecosystems, climate change significantly influences the vulnerable and fragile ecosystems of wetlands as well, having received great attention in recent decades due to its adverse impacts on water resources, forests, rangelands, agricultural lands, wetlands and, ultimately, human life (Salimi et al. 2021).

As climate change primarily affects atmospheric factors, especially temperature, and precipitation, investigating changes in such variables is of special importance for the modification of the climate change phenomena, especially in sensitive areas such as wetlands which are characterized by fragile ecosystems (Saintilan et al. 2019). In this regard, several studies have been carried out on the effects of climate change on the wetland ecosystem (for instance, Meng et al., 2016; Hossain et al., 2015; Lamsal et al., 2019, and Gómez Aíza et al., 2021).

Taking the above-mentioned facts into account, it would be of urgent necessity to study the effects of climate change and human activities on the trend of land use change in wetlands, and the prediction of such changes in the future. On the other hand, in recent years, the Jazmurian wetland has dried up because of upstream dam construction and climate change, requiring integrated management and planning to prevent further degradation of the wetland. Therefore, considering the strategic status of the Jazmurian wetland in southern Iran, a better understanding of the wetland's future trend is necessary.

In this regard, the main objectives of this study in the Jazmurian basin are as follows: (i) to evaluate the trend of land use change using remote sensing; (ii) to assess the climate change in different periods using the Statistical Down-Scaling Model (SDSM); (iii) to determine the contribution of human activities (dam construction) and environmental factors (climate change) in the trend of land use change around the wetland.

## 2. Materials and Methods

### 2.1. The Study Area

As one of the most important wetlands in Iran, the Jazmurian wetland is located between the Makran Mountain range and the Shahsavaran Mountains, enclosed by the Jebalbarez Mountains in the north and Bashagard in the south of Iran. On the other hand, the Jazmurian wetland's catchment is located between the Kerman and Sistan-Baluchestan Provinces (57º 05' to 59º 14' E and 27º 10' to 29º 15' N), whose area measures 18709.61 km$^2$ with a minimum and maximum elevation of 300m and 3865m, respectively. The Bampur River which originates from Sistan and Baluchestan and the Halil River which originates from the central highlands of Kerman Province are the main feeding sources of Jazmurian wetland. Figure (1) shows the geographical location of the Jazmurian wetland and the dams constructed on the rivers leading to it.

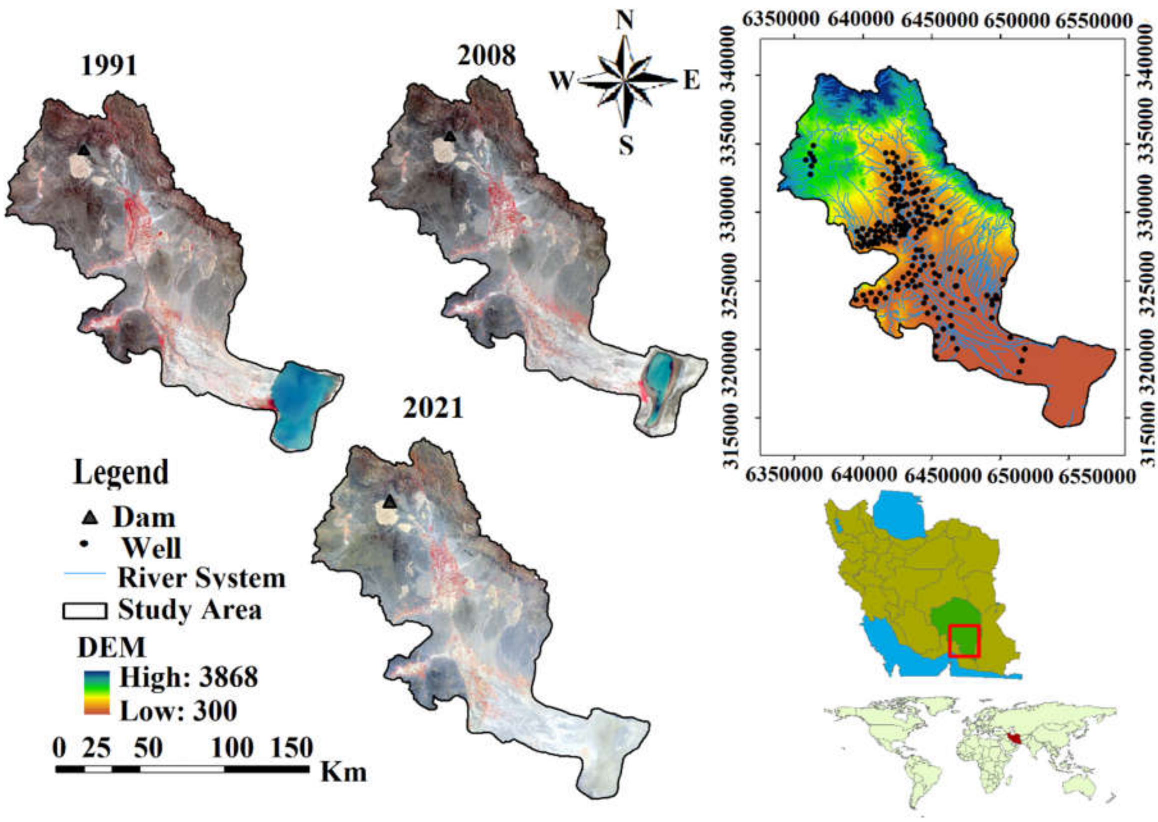


**Figure (1): The geographical location of Jazmurian wetland**

## 2.2. Methodology

### 2.2.1. Land use Change

Landslide satellite images collected from TM 1991, ETM + 2008, and OLI 2021 sensors were used to evaluate the trends of land use change in the Jazmurian wetland. Moreover, the data collected from field observations were used as extra information, and the ENVI 5.1 software was applied to process and analyze the collected satellite images. On the other hand, supervised classification and maximum likelihood methods were used to prepare the land use change maps. Then, all the cases of land use in the study area were divided into seven classes (Agricultural lands, Bare rock, Stream, Urban, Rangeland, Saltland, and Wetland). Finally, monitoring of land use change in the past and its prediction for the future was performed using the Land Change Modeler (LCM) in IDRISI Terrset software.

#### 2.2.1.1. Assessment of land use changes using Land Use Change Modeler (LCM)

Land use maps of 1991, 2008, and 2021 were selected as inputs of the Land Use Change Modeler (LCM) for the analysis of the current land use changes in the area and the prediction of land use changes in the future. The LCM model requires two land cover maps of the area at different times as inputs (Kim, 2010). Also, the decrease and increase in each land use and the net change for different classes of land cover are evaluated in the form of a map and diagram using the analysis of the model changes.

**2.2.1.2. Transition Potential Modeling**

Modeling of changes uses a set of tools allowing a group to be transmitted to a set of sub-models in order to examine the potential power of explanatory variables, which can be added to the model either as statical (invariable over time) or dynamic (time-dependent drivers) variables. In this phase of the modeling, the transition force from one land use (e.g. Rangeland) to another (e.g. agriculture) is modeled according to the explanatory variables (such as slope, distance to the river, etc.), assessing the potential that each pixel of the image has to change from one land use to another (Onate and Sendra, 2010).

At this step, three scenarios were considered for different periods, variables, and potential maps, including Scenario 1 from 1991 to 2008 with five variables (Digital Elevation Model (DEM), distance to the river, Difference in precipitation, aspect, and slope) and four transition potential maps; Scenario 2 from 2008 to 2021 with five variables (Digital Elevation Model (DEM), distance to the river, Difference in precipitation, aspect, and slope) and four transition potential maps; and Finally, scenario 3 from 1991 to 2021 with five transition variables (Digital Elevation Model (DEM), distance to the river, Difference in precipitation, aspect, and slope), and six potential transition maps.

When selecting the model variables for each scenario, each transition was modeled using logistic regression. The result in each case is a potential map for each transition representing a specific time of the change. Finally, the output of this section is a potential map for each change as an expression of the time-dependent potential of changes.

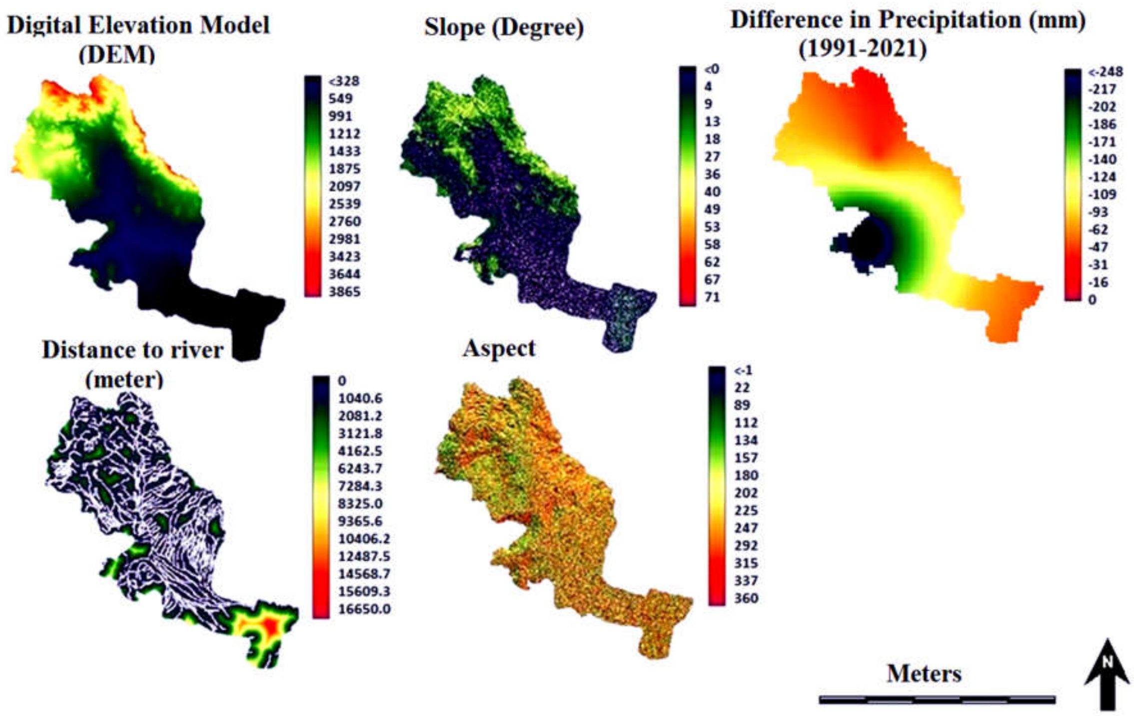


**Figure (2): The auxiliary variables are used in the LCM model for modeling the transition potential**

**2.2.1.3. Model validation for different assessment scenarios using the GEOMOD method**

To evaluate the accuracy of the model, seven parameters were used, including N (n), N (m), H (m), M (m), K (m), P (m), and P (p). Moreover, Kappa statistics of Kno, Klocation, and Kstandard were used to determine the accuracy of the model. On the other hand, model error, and prediction accuracy was calculated based on the land truth map of 2021 and the predicted map of 2021 under scenarios 1, 2, and 3, and the values of validation parameters for each of the scenarios were obtained. Finally, the scenario representing the highest coefficients was selected as the one used for predicting future land use (Klar and Donner, 1996; Paudel and Yuan, 2012).

**2.2.1.4. Predicting land use changes**

The probability of transition from each land use to another was calculated using the Markov chain. Then, modeling for 2021 was performed using a hard prediction model (Jorabian Shooshtari *et al*., 2013). Finally, Scenario 3 (1991-2021) was used for predicting land use changes in 2040. Furthermore, the change in the waterbody area of the wetland during the pre- and post-dam construction periods (1991 and 2008, respectively) was investigated to assess the impact of human activities (dam construction in the upriver of the basin) on the process of wetland degradation.

**2.2.2. Climate change**

To investigate the impact of climate change on the study area, first, the trends of changes in precipitation and temperature data over the past periods were investigated using the Mann-Kendall test, followed by the evaluation of the significance of trends in the parameters. Then, Statistical Down-Scaling Model (SDSM) was used to simulate future climatic data under the influence of the climate change phenomenon. It should be noted that the data is available on daily series for climatic variables such as precipitation, minimum and maximum temperatures, and other atmospheric parameters. Therefore, the CanESM2 data of the IPCC Fifth Assessment Report under RCP2.6, RCP4.5, and RCP8.5 scenarios were used to calculate the monthly, seasonal, and annual variations in precipitation and minimum and maximum temperature of the base period (1989-2005) compared to the future one (2021-2040).

The SDSM model uses regression statistical methods for downscaling, where the relationship between predictors (outputs of general circulation models) and predicted climatic parameters (historical data of meteorological stations) are analyzed and their empirical relationships are determined. Using correlation, variance, standard deviation, standard error of data, and the comparisons provided by the model, predictor variables are then selected for the model, which is calibrated according to the selected variables in the previous step. Finally, the calibrated model is validated using the historical data, which are then compared with the observational data (Wilby *et al*., 2002).

In the next step, using the statistics of $R^2$ (coefficient of determination) (Equation 1), root-mean-square error (RMSE) (Equation 2), and the Bias coefficient (Equation 3).

$$R^2 = \frac{\left[\sum_{i=1}^{n}(Q_{obs_i} - \overline{Q_{obs_i}})\left(Q_{sim_i} - \overline{Q_{sim_i}}\right)\right]^2}{\sum_{i=1}^{n}(Q_{obs_i} - \overline{Q_{obs_i}})^2 \sum_{i=1}^{n}(Q_{sim_i} - \overline{Q_{sim_i}})^2} \quad (1)$$

$$RMSE = \left[\frac{\sum_{i=1}^{n}(Q_{sim_i} - Q_{obs_i})^2}{n}\right]^{0.5} \quad (2)$$

$$B = \frac{1}{n}\sum_{i=1}^{n}(Q_{sim_i} - Q_{obs_i}) \quad (3)$$

In the above equations, $Q_{obsi}$ and $Q_{simi}$ are the $i_{th}$ observed and data simulated by the model, respectively, and $\overline{Q_{obs_i}}$ $\overline{Q_{sim_i}}$ are the mean observed and the data simulated by the model, respectively. Eventually, the artificial climate data for the period 2021-2040 was generated under the RCP2.6, RCP4.5, and RCP 8.5 scenarios. Table (1) shows the data used in this regard.

| Table (1): Data used in the study | |
|---|---|
| Observed (precipitation, minimum and maximum temperature) | Period |
| Kahnuj, Baft, and Miandeh of Jiroft station | 1989-2005 |
| NCEP predictors and historical data of CanESM2 | 1989-2005 |
| CanESM2 predictors | 2006-2040 |

## 3. Results and Discussion

It is necessary to study the trend of changes in wetlands during different periods. Therefore, this study investigates the trend of changes in land use before (1991) and after (2008 and 2021) the construction of Jiroft Dam to identify the influence of human factors in this regard using the remote sensing technique. To this end, the collected images were classified, followed by the preparation of land use maps via the Maximum Likelihood method. Figure (3) illustrates the land use maps of 1991, 2008, and 2021. Moreover, Table (2) shows the area of different classes in different periods in percentage (%).

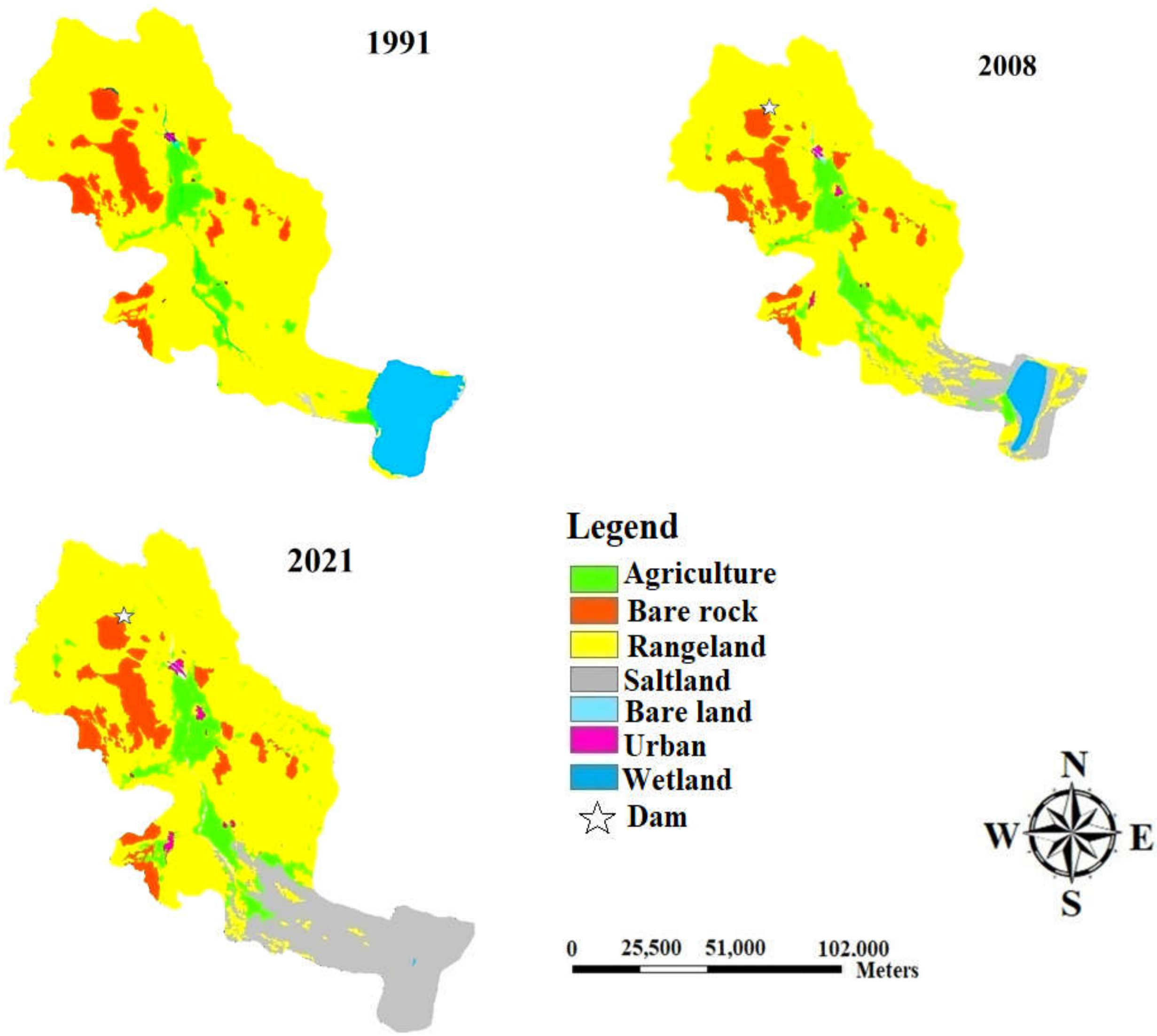


**Figure (3): Wetland land use maps in different periods**

**Table (2): The area of different classes of land use in different periods**

| Land use | 1991 | | 2008 | | 2021 | |
|---|---|---|---|---|---|---|
| | Area ($Km^2$) | Area (%) | Area ($Km^2$) | Area (%) | Area ($Km^2$) | Area (%) |
| Agriculture | 1140.61 | 6.1 | 1576.75 | 8.43 | 1576.78 | 8.43 |
| Bare rock | 1712.02 | 9.15 | 1712.27 | 9.15 | 1712.27 | 9.15 |
| Bare land | 106.82 | 0.57 | 99.5 | 0.53 | 78.53 | 0.42 |
| Urban | 24.74 | 0.13 | 46.87 | 0.25 | 96.5 | 0.52 |
| Rangeland | 13998.64 | 74.82 | 13023.78 | 69.61 | 11447.96 | 61.19 |
| Saltland | 113.34 | 0.61 | 1705.18 | 9.11 | 3795.58 | 20.28 |
| Wetland | 1613.44 | 8.62 | 546.56 | 2.92 | 1.99 | 0.01 |
| Total | 18709.61 | 100 | 18709.61 | 100 | 18709.61 | 100 |

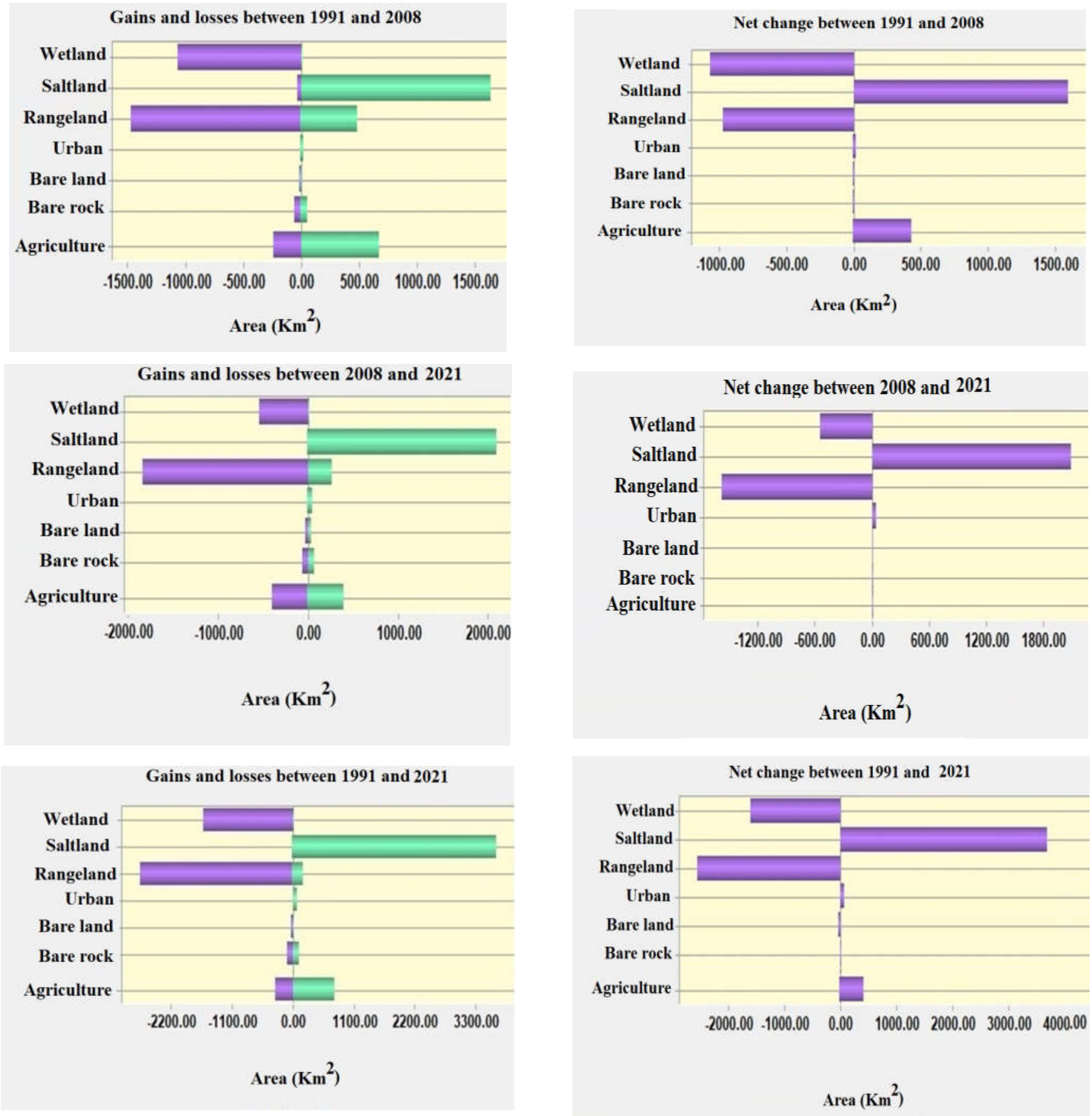


**Figure (4): Changes in different classes of land use during different periods.**

Figure (4) shows the net changes of different classes of land use in the LCM model. Accordingly, from 1991 to 202,1 the highest increase in area belonged to Saltland by 3682.24 km$^2$, and the highest decrease in area belonged to Rangeland and Wetland by 2550.68 and, 1611.45 km$^2$, respectively.

Generally, the results of land use changes during the intended periods (1991, 2008, and 2021) revealed that the wetland's water level has significantly decreased and that the wetland is exposed to destruction, with the water level having decreased from 1613.44 km$^2$ in 1991 to 546.56 and 1.99 km$^2$ in 2008 and 2021, respectively. In this regard, one of the main reasons for the significant decrease in the wetland's water level is the reduction of surface water resources entering the wetland in recent years, especially after the construction of dams on rivers flowing into the aquatic ecosystem.

However, after 1991, the water volume of the Jazmurian wetland significantly decreased due to the construction of the Jiroft dam upstream of the rivers feeding the wetland, with the surface of the wetland's lake having decreased from 2008 to 2021 compared to 1991. These results are compatible with the ones reported by Zheng et (2019) in the coastal wetland of China's Nenjiang River and Ghashghaie & Nozari (2010) in Urmia Lake.

### 3.1. Assessing the accuracy of the maps predicted by LCM using the GEOMOD method

Table (3) shows the results of model evaluation and validation for Scenario 1 (1991-2008), Scenario 2 (2008-2021), and Scenario 3 (1991-2021) using the GEOMOD method. Accordingly, it can be argued that scenario 3 with the calibration period of 1991-2021 had the highest kappa coefficients and was used for transition potential modeling because of its higher accuracy. The relatively high values of kappa coefficients indicate the LCM model's appropriate performance in simulating land use in 2021. The results are compatible with the findings reported by Oñate-Valdivieso and Sendra (2010), Johnson (2009), Anand et al. (2018), Ansari and Golabi (2019), Jahanifar et al. (2018), and Mehrabi et al. (2019).

**Table (3): Results obtained from model validation**

| Validation parameters | Value | | |
|---|---|---|---|
| | Scenario 1 | Scenario 2 | Scenario 3 |
| N(n) | 0.27 | 0.138 | 0.1111 |
| N(m), H(m) | 0.38 | 0.36 | 0.495 |
| M(m) | 0.86 | 0.95 | 0.984 |
| K(m), P(m) | 0.89 | 0.97 | 0.986 |
| P(p) | 1 | 1 | 1 |
| Kno | 0.79 | 0.94 | 0.984 |
| K location | 0.93 | 0.96 | 0.986 |
| K standard | 0.77 | 0.91 | 0.989 |

### 3.2. Transition potential modeling

After selecting sub-models and appropriate variables, the variables were entered into the model either statically or dynamically. Table (5) shows the relationship between the variables and land use using Cramer's coefficient, with a higher Cramer coefficient indicating a stronger and better relationship between the variables and land use. Therefore, a variable with a higher coefficient is of actually higher influence. According to Table (4), the variables of difference in average annual precipitation

(1991-2021) and distance to river represented the highest Cramer coefficients and correlation with land use, indicating a high correlation between land use and wetland in the catchment. Moreover, the Logistic regression model was used to model transition potential (Table 5).

**Table (4): Cramer's coefficients for different land uses under scenario 3**

| Land use/variable | Agriculture | Bare rock | Bare land | Urban | Rangeland | Saltland | Wetland |
|---|---|---|---|---|---|---|---|
| DEM | 0.175 | 0.123 | 0.08 | 0.039 | 0.2 | 0.5 | 0.11 |
| Slope | 0.08 | 0.37 | 0.06 | 0.014 | 0.03 | 0.1 | 0.04 |
| Aspect | 0.06 | 0.24 | 0.013 | 0.01 | 0.12 | 0.4 | 0.12 |
| Distance to river | 0.34 | 0.16 | 0.6 | 0.09 | 0.32 | 0.55 | 0.3 |
| The difference in Precipitation (1991-2021) | 0.31 | 0.35 | 0.12 | 0.087 | 0.67 | 0.87 | 0.59 |

**Table (5): Logistic regression results for predicting transition potential in LCM**

| Submodel | ROC |
|---|---|
| Rangeland to Saltland | 0.98 |
| Wetland to Saltland | 0.93 |
| Rangeland to Agriculture | 0.79 |
| Agriculture to Saltland | 0.97 |
| Rangeland to Urban | 0.85 |
| Agriculture to Urban | 0.67 |

### 3.3. Predicting land use changes

At this step, the probability of transition to each land use was determined using the Markov chain (Table 6). As shown in Table (6), the maximum probability of transition belongs to the conversion of wetland waterbody to salt land. Then, the predicted land use map of 2040 was prepared using Scenario 3 and the Markov chain (Figure 8). Figure (5) shows the land use map predicted by LCM for 2040.

**Table (6): The calculated transition probability matrix via the Markov chain under scenario 3**

| | 2021 | | | | | |
|---|---|---|---|---|---|---|
| 1991 | Agriculture | Bare rock | Urban | Rangeland | Saltland | Wetland |
| Agriculture | 0.944 | 0 | 0.0173 | 0 | 0.038 | 0 |
| Bare rock | 0 | 1 | 0 | 0 | 0 | 0 |
| Urban | 0 | 0 | 1 | 0 | 0 | 0 |
| Rangeland | 0.143 | 0 | 0.0348 | 0.62 | 0.201 | 0 |
| Saltland | 0 | 0 | 0 | 0 | 1 | 0 |
| Wetland | 0 | 0 | 0 | 0 | 0.996 | 0.003 |

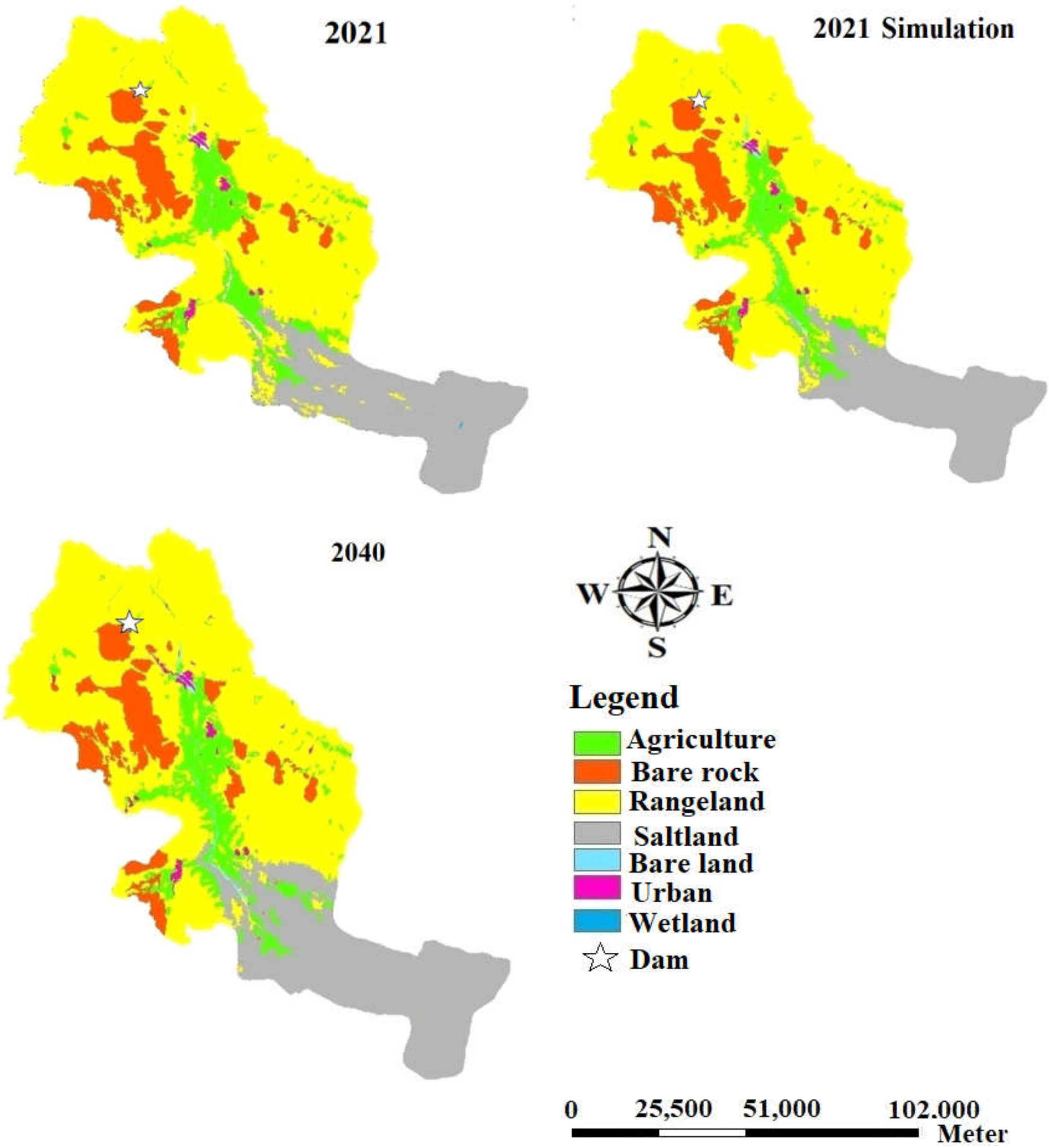


**Figure (5): Land use map of Jazmurian wetland (under scenario 3)**

Figure (5) shows the area (%) of different land uses in 2040, whose changes indicate that by 2040 (compared to 2021), the area of salt lands and agriculture lands will increase by 847.96 and 120.94 km$^2$, respectively, and the rangeland area will decrease by 999.93 km$^2$ (Table 7). Moreover, the area of rangelands will significantly decrease from 13998.64 km$^2$ in 1991 to 3550.61 km$^2$ in 2040. Such a decrease is in line with the conversion of these lands into agricultural lands, salt lands, and residential lands, according to which the area of agricultural lands will increase by 120.97 in 2040 compared to 2021, and the wetland will be completely dried and converted to salt lands.

The reduced wetland area will be due to dam construction upstream of the Halil River that feeds the Jazmurian wetland, leading to a decrease in precipitation as a result of climate change. Moreover, over-exploitation of groundwater (especially digging illegal wells) with the aim of increasing the area under crop cultivation, and the occurrence of meteorological and hydrological droughts may also contribute to reducing the area of the wetland's lake.

On the other hand, as shown in Figure (5), the land use of urban and residential areas has increased, with the rapid growth of population and urbanization having created high tensions in this area. Moreover, the increasing demand for water in urban and rural areas of Jiroft and Anbarabad cities and the rapid population growth in this area has caused a sharp decline in groundwater levels, posing a threat to the agricultural lands, Jazmurian wetland, and inhabitants of the riverside.

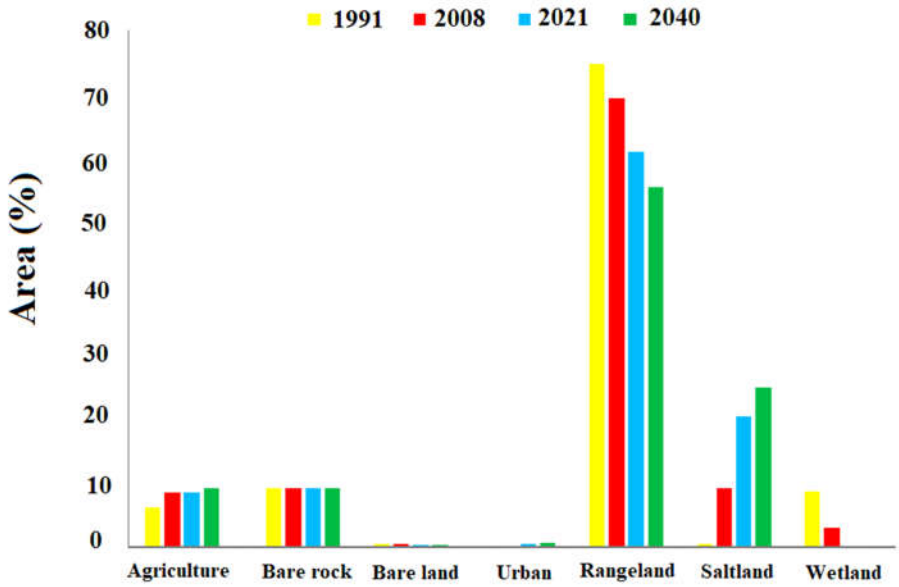


**Figure (6): The area of different land uses (%) in different years compared to 2040**

**Table (7): The area of different classes of land use in 2021 and 2040**

| Land use | 2021 | | 2040 | |
|---|---|---|---|---|
| | Area ($Km^2$) | Area (%) | Area ($Km^2$) | Area (%) |
| Agriculture | 1576.78 | 8.43 | 1697.72 | 9.07 |
| Bare rock | 1712.27 | 9.15 | 1712.27 | 9.15 |
| Bare land | 78.53 | 0.42 | 78.53 | 0.42 |
| urban | 96.5 | 0.52 | 129.52 | 0.69 |
| Rangeland | 11447.96 | 61.19 | 10448.03 | 55.84 |
| Saltland | 3795.58 | 20.28 | 4643.54 | 24.82 |
| Wetland | 1.99 | 0.01 | 0 | 0 |
| Total | 18709.61 | 100 | 18709.61 | 100 |

### 3.4. Climate change

After assessing the land use, the trends of changes in temperature and precipitation data were analyzed using the Mann-Kendall test to investigate the impact of climate change on the studied area. The results of the Mann-Kendall test performed on all of the stations located at the base period indicated a significant decreasing trend in precipitation data and a significant increasing trend in minimum and maximum temperature (Table 8).

**Table (8): The results of Mann Kendall test at synoptic stations (1989-2005)**

| Station | Parameters | Period | Kendall's tau | P-value | Alpha | Trend |
|---|---|---|---|---|---|---|
| Baft | Precipitation | 1989-2005 | -0.147 | 0.0434 | 0.05 | Sig. |
| | Tmax | | 0.382 | 0.036 | 0.05 | Sig. |
| | Tmin | | 0.544 | 0.003 | 0.05 | Sig |
| Kahnoj | Precipitation | 1989-2005 | -0.162 | 0.0387 | 0.05 | Sig. |
| | Tmax | | 0.338 | 0.034 | 0.05 | Sig. |
| | Tmin | | 0.544 | 0.003 | 0.05 | Sig. |
| Miandeh Jiroft | Precipitation | 1989-2005 | -0.397 | 0.029 | 0.05 | Sig. |
| | Tmax | | 0.412 | 0.023 | 0.05 | Sig. |
| | Tmin | | 0.382 | 0.036 | 0.05 | Sig. |

The SDSM was used for downscaling climatic parameters, whose accuracy was assessed by comparing the data produced by the model and the actual (observed) data in the base period using $R^2$ (coefficient of determination), RMSE, and Bias coefficient (Table 9). Accordingly, considering the high coefficient of determination ($R^2$) and low RMSE and Bias coefficient for all three climatic parameters evaluated at all of the stations, it could be argued that the model bears high modeling accuracy.

**Table (9): Calibration statistics of climatic parameters at synoptic stations**

| Station | Statistical factors | Parameters: Tmin | Tmax | Prec |
|---|---|---|---|---|
| Kahnoj | $R^2$ | 0.99 | 0.99 | 0.67 |
| | RMSE | 1.36 | 1.81 | 16.19 |
| | Bias | 0.42 | -0.01 | 1.30 |
| Baft | $R^2$ | 0.99 | 0.99 | 0.97 |
| | RMSE | 1.50 | 1.97 | 7.28 |
| | Bias | 0.25 | 0.22 | -4.83 |
| Miandeh Jiroft | $R^2$ | 1.00 | 1.00 | 0.80 |
| | RMSE | 1.41 | 0.69 | 15.67 |
| | Bias | 1.02 | -0.09 | 1.72 |

After assuring the SDSM potential to produce climatic data, the model was run for downscaling the general circulation model data and producing artificial data for predicting climate change in the period 2021-2040. Then, following the running of the model and the production of daily values of minimum and maximum temperature and precipitation rate for the future periods, one can determine the future climatic conditions for the Jazmurian wetland (Table 10).

Table (11) shows the changes in climatic parameters for the period 2021-2040 compared to the base period (1989-2005). As indicated by the results, compared to the base period, the average annual precipitation will decrease in the future at all stations under the RCP2.6, RCP4.5, and RCP8.5 scenarios, with its highest decrease being 50.4% under RCP 8.5 at Baft station. Moreover, the average annual minimum and maximum temperature rates will increase by 3 and 2.56 °C under RCP 8.5, respectively (Figures 7 to 9).

Overall, the investigation of climatic parameters through the SDSM showed a decrease in precipitation and an increase in temperature in the future, which is in line with the results found by Gohari et al., 2017; Kouhestani et al., 2017; Saymohammadi et al., 2017; Lamsal et al., 2019, and Zehtabian et al., 2016. Therefore, it could be argued that increasing salt lands and wetland dryness, decreasing precipitation, and increasing temperature will turn the wetland into a dust hotspot in the future, requiring some management measures to rehabilitate the wetland.

**Table (10): Climatic parameters in the base period and future period under different scenarios**

| Station | Parameters | Baseline | RCP 2.6 | RCP 4.5 | RCP 8.5 |
|---|---|---|---|---|---|
| Miandeh jiroft | Precipitation (mm) | 310.5 | 278.6 | 265.4 | 234.1 |
| | Tmax (°C) | 33 | 33.5 | 33.7 | 33.9 |
| | Tmin(°C) | 16 | 17.5 | 17.7 | 17.9 |
| Kahnoj | Precipitation (mm) | 298.3 | 286.6 | 281.4 | 279.3 |
| | Tmax (°C) | 32.6 | 34.7 | 34.8 | 35 |
| | Tmin(°C) | 18.6 | 20.8 | 21 | 21.6 |
| Baft | Precipitation (mm) | 314.7 | 206.7 | 188.4 | 156 |
| | Tmax (°C) | 19.7 | 21.7 | 22.1 | 22.2 |
| | Tmin(°C) | 7.3 | 8.8 | 8.9 | 9.2 |

**Table (11): Changes in climatic parameters for future periods under different scenarios compared to the base period**

| Station | Parameters | RCP 2.6 | RCP 4.5 | RCP 8.5 |
|---|---|---|---|---|
| Miandeh jiroft | Precipitation (%) | -10.3 | -14.5 | -24.6 |
| | Tmax (°C) | 0.5 | 0.7 | 0.9 |
| | Tmin(°C) | 1.5 | 1.7 | 1.9 |
| Kahnoj | Precipitation (%) | -3.91 | -5.7 | -6.4 |
| | Tmax (°C) | 2.1 | 2.2 | 2.4 |
| | Tmin(°C) | 2.21 | 2.42 | 3.0 |
| Baft | Precipitation (%) | -34.32 | -40.12 | -50.41 |
| | Tmax (°C) | 2.07 | 2.43 | 2.56 |
| | Tmin(°C) | 1.46 | 1.61 | 1.86 |

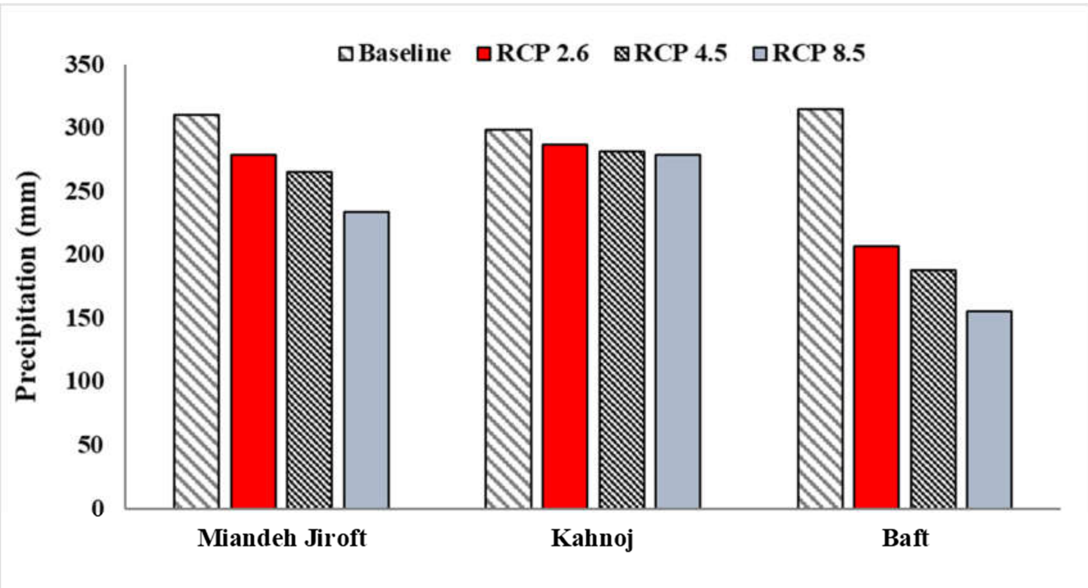


**Figure (7): Annual average precipitation under RCP of different scenarios compared to the base period**

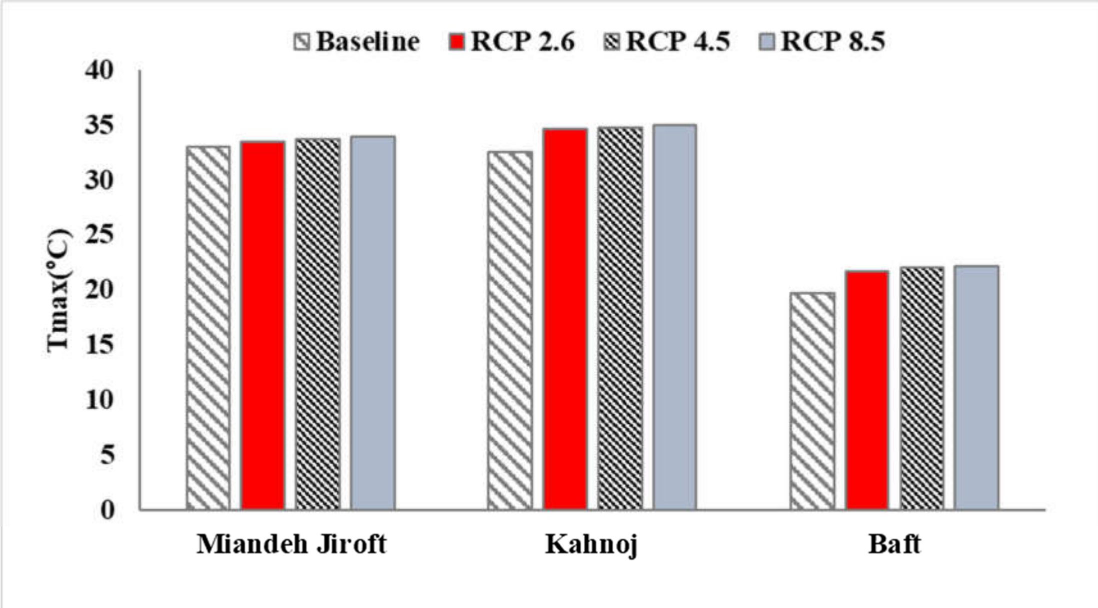


**Figure (8): Maximum temperature rate under RCP of different scenarios compared to the base period**

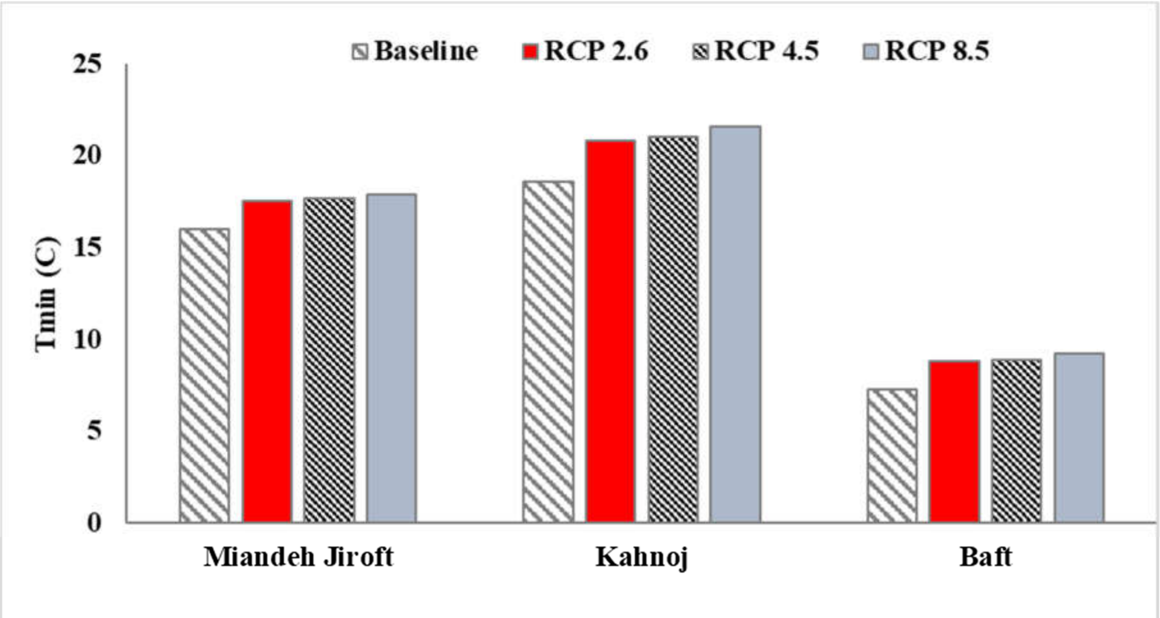


**Figure (9): Minimum temperature rate under RCP of different scenarios compared to the base period**

## 4. Conclusion

The results of the land use change analysis indicated that the area of Jazmurian wetland's lake has decreased by 1611.45 $km^2$ from 1991 to 2021 and that the trend of land use changes in the future is significant, leading to an increase in the area of agricultural lands and salt lands, and thus, complete dryness of the wetland. Moreover, the evaluation of climate change and climatic parameters in the study area revealed a decreasing trend in precipitation and an increasing trend in minimum and maximum temperature rates in the past and future. Therefore, reduced precipitation and increased temperature in the past and future, and the construction of the Jiroft dam upstream of the Jazmurian wetland can be considered as factors causing a decrease in the water supply of the wetland, the decrease in the wetland's area, and changes in the wetland's surrounding ecosystems. Finally, it could be argued that the decrease in the area of the wetland's lake and an increase in salt lands will lead to the expansion of arid lands as sources of dust storms.

Generally, evaluating the impact of land use and climate change on wetland dryness via modeling methods is a good idea but it is not sufficient. More quantitative analyses are required to determine and assess the ecosystem changes using landscape metrics, a method broadly applied in landscape ecology. Moreover, incorporating landscape metrics with remote sensing can be a useful tool to monitor land degradation and assess different structural dimensions of land use changes, including distribution, size, shape, heterogeneity, shape complexity, and fragmentation. Therefore, it is recommended that future studies apply landscape metrics to the assessment of wetland land degradation.

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