Spatial-Temporal Analysis of Dam Construction on Climate Change (Temperature and Relative Humidity)

Saeed Behzadi[1], Maryam Abbaspour[2]

[1] Shahid Rajaee Teacher Training University, Tehran, Iran, behzadi.saeed@gmail.com
[2] University of Science and Technology of Iran, Tehran, Iran, abbaspour_maryam81@yahoo.com

Abstract: The artificial lakes that form behind the dams create a considerable level of evaporation that can have significant effects on the microclimate (the area around the dam). If other environmental factors for precipitation are provided, this increase in the volume of atmospheric moisture can affect the temporal and spatial distribution of rainfall. In this research, the effects of the regional climate in the downstream area of Taleghan are studied by examining different climatic parameters in the period before and after the construction of the dam. In general, the construction of Taleghan Dam has many advantages such as lowering the average annual temperature, increasing relative humidity, supplying river water in the rainy season, and even signs of increasing light rainfall in the downstream region. Negative effects can also be seen in the downstream areas, such as imbalance and changes in the amplitude of fluctuations in the values of various parameters, or the warming of hot seasons and the cooling of cold seasons. In general, changes along the river downstream can be intensified or adjusted, but these effects are reduced by moving away from the river bank. In this study, meteorological, hydrometric, vegetation, and soil moisture parameters are analyzed separately. Then the changes in the extremes of these parameters are investigated. Finally, the changes resulting from the construction of Taleghan Dam in spatial and temporal dimensions are revealed by defining a composite index.
Keywords: Spatial Information System, Vegetation, Temperature, Spatial Analysis.

1. Introduction

In the past years, according to the specific geographical conditions, and needs of the residents, they have constructed a dam or reservoir to meet their needs for irrigation and water supply. In some areas, due to low river water levels or the need to change the direction of the river, a dam was built to increase the water level for agricultural, and development purposes and to prevent floods [1-3].

The positive effects of the dam construction on anyone are not hidden. Despite the widespread publicity about the benefits of dams, the various consequences on the livelihoods, ecosystems, and climate of the region and surrounding villages is an issue that has been neglected from the beginning [1]. In principle, the negative effects of dam construction may become apparent years after the construction of the dam. These effects include the emission of greenhouse gases from sediments in the bottom of the dam reservoir, disruption of irrigation regimes and ecosystem change, submergence of settlements and agricultural and residential land, as well as cultural and historical

[1] Corresponding Author: Assistant Professor in Suveying Engineering, Faculty of Civil Engineering, Shahid Rajaee Teacher Training University, Lavizan, Tehran, Iran, E-mail addresses: behzadi.saeed@gmail.com, Tel: (+98) 21 22970021, Fax: (+98) 21 22970021
[2] Lecturer

heritage or drainage of dams, forced population displacement due to job loss (such as farmers), transportation problems for residents with flooding of roads, etc. [4, 5].
One of the negative and destructive effects of dam construction on a river is the release of hazardous greenhouse gases from the main reservoir in the long run. Rising greenhouse gases and subsequent rising temperatures in recent decades have upset the climate balance in most parts of the world. Studies show that this phenomenon can have negative effects on various sectors including water resources, agriculture, environment, health, industry, and economy. The least change in the average rainfall and temperature has destructive effects on the agricultural and economic sectors. In recent years, drought has caused a lot of damage in our country. Therefore, predicting changes in the amount and trend of climate variables for use in macro-planning, especially concerning natural disaster risk management seems necessary [6].
The construction of the dam can also affect the rainfall patterns of the region. Precipitation (one of the main parameters in this study) is the most vital climatic element that plays a major role in human life. The location of more than 90% of the country's area in arid and low water areas of the world and the existence of numerous dry periods and their dominance over wet periods in most parts of the country have attracted the attention of many researchers [7, 8].
Given the above, the construction of a dam on a river can have various positive and negative effects on the region, which may gradually intensify in the long run and have irreparable consequences. On the other hand, through proper management of dam outputs, the negative impact can be significantly reduced and added to the positive results of dam construction in the region. Therefore, it seems necessary to study the relationship between different climatic parameters such as meteorological indicators, hydrometric, soil moisture, land use, etc. [9]. This study intends to analyse the spatial and temporal changes in various aspects of the climate downstream of the Taleghan Dam.

2. Research Method

Today, satellite imagery is widely available at a very low cost and even free, so using remote sensing data to model climate data seems like a convenient and cost-effective method [10, 11]. The Standardized Precipitation Index (SPI), Normalized Difference Vegetation Index (NDVI), and Land Temperature Index (LST) [12, 13] are considered as the most important meteorological indexes in modelling and forecasting the time series of drought. On the other side, four important machine learning methods namely Neural Network (NN) [14, 15], Support Vector Regression (SVR) [16], Least Squares Support Vector Machine (LSSVM) as well as a fuzzy system [17-19], plays an important role in modeling and simulation this phenomenon [20].
Due to serious limitations in the number of meteorological and ground hydrometric stations and also the lack of information for the period before the construction of Taleghan Dam, it is necessary to use satellite images as the main source of information required for research. Therefore, for meteorological, hydrometric, vegetation, and soil moisture quantities, the relationship between Landsat 7 satellite imagery and ground station data using various machine learning methods including neural network, ANFIS, some examples of the most famous methods Classification, Regression, SVM, Gaussian

Process Regression and two methods of Ensemble method are examined and then different methods are compared to find the optimal method [21, 22].
On the other hand, this study intends to examine the temporal dimension of climate change in the region along with the spatial dimension, which is another reason for using satellite images [23].
In this method, for 7 years from the period before the date of operation of the dam, 7 years appropriate to the period after the dam is considered according to the available data and the type of average weather conditions. Then, the new parameter that includes the time dimension of this research, before and after dewatering of the dam, is calculated using Equation 1 for the desired 7-year period. In this method, a limited number of small fluctuations may be lost due to the proportions that are calculated, but the changes made by the dam in the area can be better displayed and the complexity of the time analysis can be reduced.

$$TP=\frac{y_{post}-y_{pre}}{y_{post}+y_{pre}} \qquad (1)$$

TP is the time parameter that shows the time changes later than before the construction of the dam, ypost and ypre are the values of the initial climatic parameters after and before the dam. The spatial dimension can also be included in this relation, in which case the above relation is generalized to relation 4-2 [8]:

$$STP=\frac{\frac{x_{post}-x_{pre}}{x_{post}+x_{pre}}}{\frac{y_{post}-y_{pre}}{y_{post}+y_{pre}}} \qquad (2)$$

STP is, in fact, a spatio-temporal parameter that in addition to the temporal aspect, also includes the spatial dimension, the downstream to the upstream ratio of the dam, x and y are the primary climatic parameters downstream and upstream of the dam, respectively.
In this research, most of the required information is extracted from satellite images and machine learning methods, from two methods 1) PCA and 2) a statistical method using Equations 3-4 to prepare bands. Optimally used to enter machine learning algorithms for modelling climatic parameters [7].

$$OIF=\frac{(std(B1)+std(B2)+std(P))}{¿corr(B1,B2)\vee+¿corr(B1,P)\vee+¿corr(B2,P)\vee¿¿} \qquad (3)$$

The Optim Index Factor (OIF) is called the optimal factor. The larger the number, the greater the correlation between the B1 and B2 bands in terms of statistical dependencies. Of course, to make the relationship shorter and more understandable, in this equation, a binary combination of satellite image bands is considered, but in the operational process of the research, a combination of four of these bands has been used.

3. Study Area

The study area is divided into two parts. The first region includes three provinces of Tehran, Alborz, and Qazvin. The region has six climatic sub-regions including arid, semi-arid, Mediterranean, semi-humid, humid, and very humid. The second region is the main region of this research to study the spatial and temporal changes of climatic phenomena at the local scale, which includes the downstream area of Taleghan Dam. Figure 1 shows the study area. On the other hand, this research intends to examine the spatial aspect of changes as well as the temporal aspect, so more than two ground stations are needed to produce the required maps. Due to the impossibility of providing such conditions in the study area, it was decided to compensate for the lack of information in terms of time and space through Landsat 7 satellite images.
In this research, first, all meteorological and hydrometric stations of Tehran, Alborz, and Qazvin provinces were used to model the desired climatic parameters in machine learning algorithms, but the main study area of this research is the downstream part of Taleghan Dam, which is shown in Figure 1 [24, 25]. In terms of time, this research uses Landsat 7 satellite images from 1999 to 2019.
First of all, to measure each of these indicators, the raw values of the spectral bands must be converted to reflectance values. After calculating the reflection values of the spectral bands, the atmospheric correction was performed using the flash method in the Python programming environment for all images, then the pixel values were extracted in the spatial coordinates of meteorological and hydrometric stations.
The climatic parameters that have received the most impact from the construction of the dam have been identified, and it proves that these parameters are related to the main outlets of the dam, namely discharge and river sediment. To achieve these goals, meteorological and hydrometric data are examined in two stages.

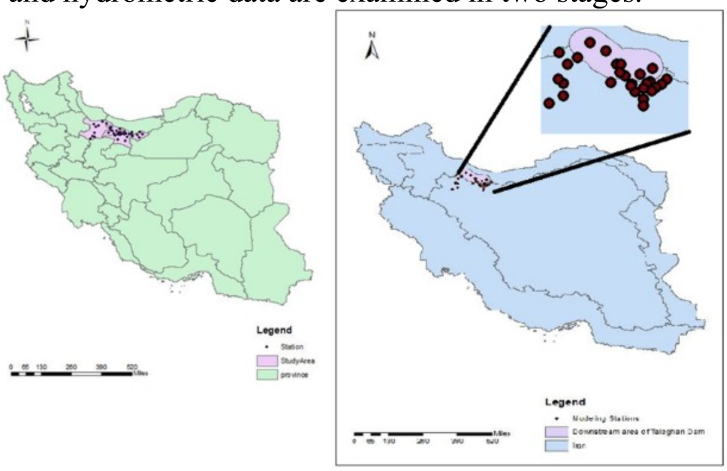

Figure 1. Study area and dispersion of the desired stations

4. Data Analysis

Regarding meteorological parameters, it is not easy to determine how much these changes are related to the construction of the dam by examining the statistics recorded in meteorological stations. After examining several climatic parameters, it is better to understand how difficult it can be to assess such changes simply by analysing the statistics. In general, the temperature has an increasing trend, after the construction of the dam, the lower and upper extremities have changed towards higher values. Also, the increase in the number of days of the year that have higher temperatures can be seen from the observations in the upper parts. Moreover, Figures 2 and 3 show that the intensity of the changes increases with distance from the dam along the river and decreases with distance from the width of the river.

Figure 4 and 5 fully confirms the spatial distribution of the analyzed changes similar to what has been increased in the spatial distribution maps related to relative humidity around the main reservoir of the dam.

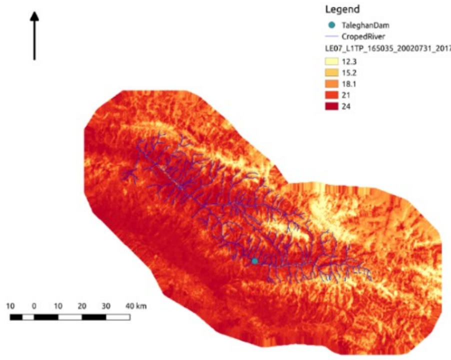

Figure 2. Spatial distribution of average temperature index before the construction of Taleghan Dam

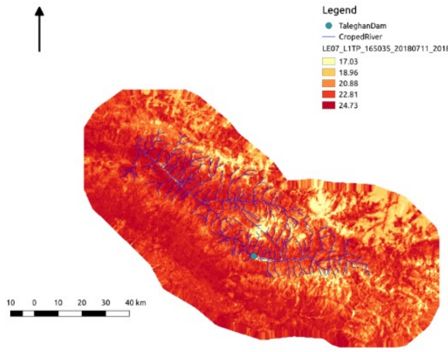

Figure 3. Spatial distribution of average temperature index after the construction of Taleghan Dam

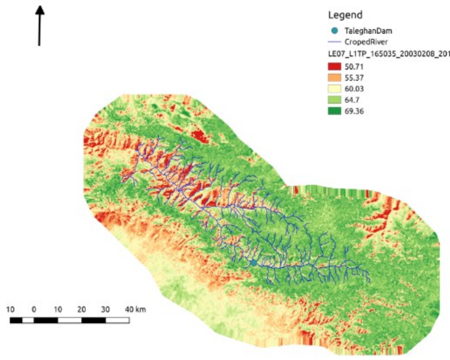

Figure 4. Spatial distribution of relative humidity index before the construction of Taleghan Dam

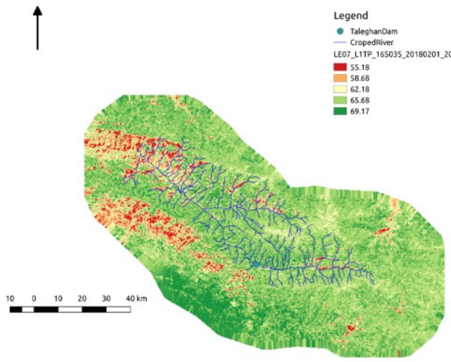

Figure 5. Spatial distribution of relative humidity index after the construction of Taleghan Dam

5. Evaluation Of Extreme Indicators

In the study of climate change in a region, the analysis of extreme indicators is critical because the slightest change in the extremes of the region is vital and can be catastrophic for the region. In this study, to study the changes in the climatic extremes of the region, two extreme indicators for each of the climatic parameters of the region were calculated and their changes in the periods before and after the construction of the Taleghan dam were analysed. These indicators include 1% of the number of days of the year in which the parameter values are in the top 20% of the range of recorded observations for the region (upper extreme index 2% of the number of days in the year in which the parameter values are in the bottom 10% of the observed range of observations for the area (Lower extremity index). Because the study area is arid or semi-arid, 20% was used for the indicators related to the maximum observations to have a measurable result (Figure 6).

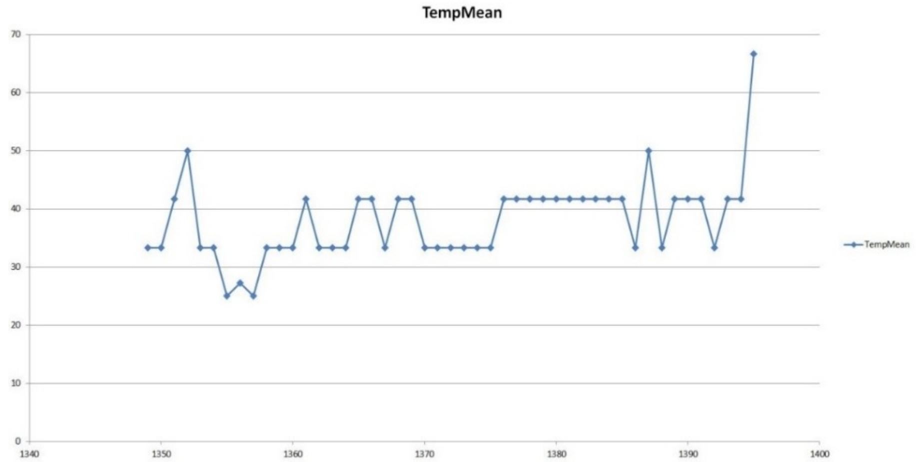

Figure 6. Time series of the upper extreme index of the average temperature downstream of Taleghan Dam

The result of changes in the high extreme index for the minimum temperature statistics of the region in Figure 7 indicates an increase in the number of days of the year with a minimum temperature, but there is no sign of exceeding the allowable values compared to previous years. It should be noted that the analyses performed up to this stage of work only prove that after the construction of the Taleghan Dam in the downstream region, they have changed, either positive or negative, and until this stage, it is not possible to say with certainty how much Changes have occurred due to the construction of the dam in the area.

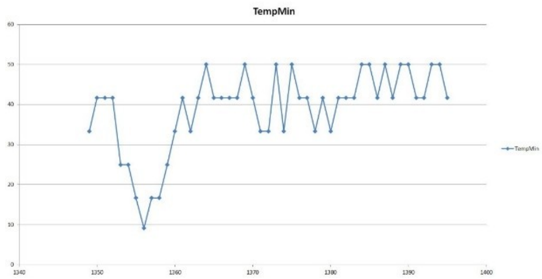

Figure 7. Time series of the upper extreme index of the minimum temperature downstream of Taleghan Dam

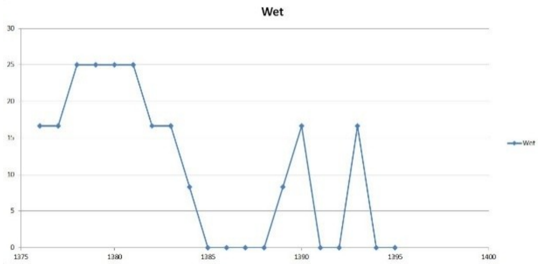

Figure 8. Time series of the upper extreme index for relative humidity in the downstream area of Taleghan Dam

Fluctuations in the years following the construction of the dam in Figure 8 indicate a disturbance and relative reduction in the high extreme values of the relative humidity observations. In other words, the number of days of the year when the relative humidity values are in the upper, the relative humidity has been decreasing on average and they have suffered from irregular disturbances. On the other hand, the lower extremity in Figure 9 decreases sharply in the period after the construction of the dam, and it can be said that this change is positive because the upper extremity also has a significant decrease in relative humidity, so it can be concluded that in After the construction of the dam in the downstream area, most days of the year, even the rainless seasons, had moderate and below-average relative humidity.

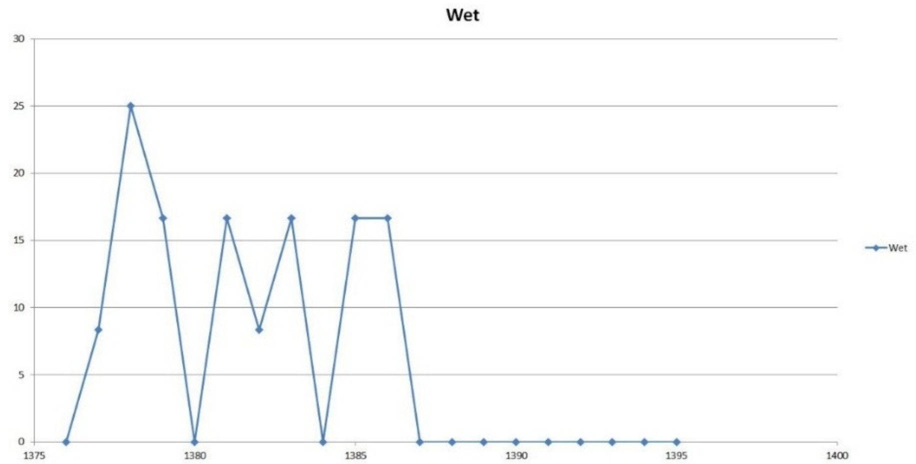

Figure 9. Time series of the lower extreme index for relative humidity in the downstream area of Taleghan Dam

6. Conclusion

Measuring data and combining them, as well as examining the effectiveness of using methods such as PCA and OIF statistical index to prepare data for entry. The model examined appropriate solutions for modelling and data mining. According to the results obtained in the previous section, the artificial neural network model had acceptable performance in both methods and it was quite obvious that the impact of database preparation methods to enter the algorithm and produce a new model could be significant. . Since so far not enough attention has been paid to the discussion of data preparation to enter the modelling algorithms, and considering the significant impact of this on the results of the obtained models, it is suggested that more attention be paid to this discussion in future research.

The phenomenon of dam construction has quite significant effects on climatic parameters. Large lakes that form behind reservoir dams create large levels of evaporation that can cause significant changes in the microclimate (the area around the dam lake). Usually, the average air temperature decreases and it has a climate with more humidity. On the other hand, the volume of water added to the atmosphere if other factors can affect the temporal and spatial distribution of precipitation. But on the other hand, the construction of the dam can have different effects on the climate of the downstream area, which has a great dependence on how the dam is managed. According to the obtained results, it can be said that by moving away from the dam reservoir downstream, the negative effects are gradually intensified and as we get closer to the dam reservoir, the positive effects become more visible.

Decisions based solely on the spatial distribution layer or time-series diagram of an indicator can have only a descriptive aspect, and on issues such as the study of climate change in an area, due to the dependence of climate on a large number of climate parameters, each aspect and characteristics A particular climate indicates an area can be very complex and annoying and incomprehensible to non-experts in decision-making, such as managers and politicians. Therefore, the definition of an index that includes the most important features of a region's climate along with spatial and temporal dimensions so that using this index can easily quantify the spatial and temporal changes of a phenomenon such as regional climate attractive and vital. And as explained in detail in the previous sections, changes along the river downstream can also be intensified or adjusted, but these effects are reduced by moving away from the river bank. In general, the construction of Taleghan Dam has many advantages over the lower region, such as lowering the average annual temperature, increasing relative humidity, supplying river water in rainy seasons, and even signs of increasing low rainfall, but this point should not be forgotten. The negative effects of dam construction on rivers in the long run gradually become apparent, and poor management of this vital phenomenon may have irreparable consequences on the ecosystem of the region.

References

[1] Brown PH, Tullos D, Tilt B, Magee D, Wolf AT. Modeling the costs and benefits of dam construction from a multidisciplinary perspective. J Environ Manage. 2009;90:S303-S11.
[2] Gray V. Climate change 2007: the physical science basis summary for policymakers. Energy & Environment. 2007;18(3-4):433-40.
[3] Jalilzadeh A, Behzadi S. Flood Mapping and Estimation of Flood Water-Level Using Fuzzy Method and Remote Sensing Imagery (Case Study: Golestan Province, Iran). Forum Geografic: University of Craiova, Department of Geography; 2020. p. 165.
[4] SHIRAVAND H, KHALEDI S, BEHZADI S, Shokri SHA. Monitoring and assessing the changes in the coverage and decline of oak forests in Lorestan Province using Satellite Images and BFAST Model. 2020.
[5] Jabbari M, Behzadi S. Modelling Effects of Land Use Changes on Traffic based on Proposed Traffic Simulator. Computational Engineering and Physical Modeling. 2019;2(3):61-70.
[6] Shiravand H, Khaledi S, Behzadi S. Evaluation and Prediction of Decline of Oak Forests in Middle Zagros (Lorestan Section) with a Climate Change Approach. Iranian Journal of Forest and Range Protection Research. 2019;17(1):64-81.
[7] Norouzi E, Behzadi S. Evaluating machine learning methods and satellite images to estimate combined climatic indices. International Journal of Numerical Methods in Civil Engineering. 2019;4(1):30-8.
[8] Norouzi E, Behzadi S. The Feasibility of Machine-learning Methods to Extract the Surface Evaporation Quantity using Satellite Imagery. Journal of Electrical and Computer Engineering Innovations (JECEI). 2021;9(2):229-38.
[9] Soufi M, Behzadi S, Aghamohammadi H. Developing a Baseline Approach for Modeling Land use Change. Journal of Geomatics Science and Technology. 2018;7(4):103-18.
[10] Jalilzadeh A, Behzadi S. Machine Learning Method for predicting the depth of shallow lakes Using Multi-Band Remote Sensing Images. Soft Computing in Civil Engineering. 2019;3(2):59-68.

[11] Torabi G, Aghamahammadi Zanjirabad H, Behzadi S. Monitoring the status of Bakhtegan Lake and surrounding areas using satellite imagery and computational intelligence. Iranian journal of Ecohydrology. 2018;5(1):251-63.
[12] Chatrsimab Z, Alesheikh A, Vosoghi B, Behzadi S, Modiri M. Land Subsidence Modelling Using Particle Swarm Optimization Algorithm and Differential Interferometry Synthetic Aperture Radar. ECOPERSIA. 2020;8(2):77-87.
[13] Chatrsimab Z, Alesheikh AA, Voosoghi B, Behzadi S, Modiri M. Development of a Land Subsidence Forecasting Model Using Small Baseline Subset—Differential Synthetic Aperture Radar Interferometry and Particle Swarm Optimization—Random Forest (Case Study: Tehran-Karaj-Shahriyar Aquifer, Iran). Dokl Earth Sci: Springer; 2020. p. 718-25.
[14] Ghasempoor Z, Behzadi S. Traffic Modeling and Prediction Using Basic Neural Network and Wavelet Neural Network Along with Traffic Optimization Using Genetic Algorithm, Particle Swarm, and Colonial Competition. Journal of Geomatics Science and Technology. 2021;10(3):147-63.
[15] Ahmadi M, Behzadi S. The Process of Evaluating Magnesium Changes Using Neural Network and Geospatial Information System In the villages of Gonbad city (Golestan province). Scientific-Research Quarterly of Geographical Data (SEPEHR). 2016;25(99):29-42.
[16] Jafarian H, Behzadi S. Evaluation of PM2. 5 emissions in Tehran by means of remote sensing and regression models. Pollution. 2020;6(3):521-9.
[17] Mahjoobi M, Behzadi S. Solar desalination site selection on the Caspian Sea coast using AHP and fuzzy logic methods. Modeling Earth Systems and Environment. 2022:1-9.
[18] Mousavi Z, Behzadi S. Geo-Portal Implementation with a Combined Approach of AHP and SWOT. International Journal of Natural Sciences Research. 2019;7(1):23-31.
[19] Behzadi S, Mousavi Z, Norouzi E. Mapping Historical Water-Supply Qanat Based On Fuzzy Method. An Application to the Isfahan Qanat (Isfahan, Iran). International Journal of Numerical Methods in Civil Engineering. 2019;3(4):24-32.
[20] Behzadi S, Alesheikh AA. Cellular Automata vs. Object-Automata in Traffic Simulation. International Journal of Remote Sensing Applications. 2014;4(1):61-9.
[21] Behzadi S, Hamoudzadeh A. Evaluation of effective factors on air pollution using optimized cellular automata: A case study of Tehran. Journal of Engineering Research. 2021.
[22] Hamoudzadeh A, Behzadi S. Predicting user's next location using machine learning algorithms. Spatial Information Research. 2020:1-9.
[23] Barzegari S, Agahamohammadi H, Behzadi S. Development of a Strategy Using Spatial Analysis and Neural Network for Spatial Analysis of Water Levels at the Time of Drought. Journal of Geomatics Science and Technology. 2020;9(3):73-84.
[24] Shahmoradi A, Behzadi S. Optimum Routing in the Urban Transportation Network by Integrating Genetic Meta-heuristic (GA) and Tabu Search (Ts) Algorithms. Journal of Geomatics Science and Technology. 2020;9(3):145-58.
[25] Behzadi S. An intelligent location and state reorganization of traffic signal. Geodesy and Cartography. 2020;46(3):145-50.