Original Research Article

Investigating the changes of water basins by remote sensing method (Case study: Lake Tar and Hoyer)

Abstract

In recent studies several factors such as landslides, volcanoes, glaciers, tectonic factors and karst forms such as flooded pulleys resulting of karsts development cause the formation of lakes in mountainous areas. The mountain lakes of Iran, including Tar and Havir lakes, are mainly formed by landslides. In this research investigation of water basins changes for (Tar and Hoyer lakes) by remote sensing method in the period from 2013 to 2022 have been done. It has been tried to select appropriate Landsat 8 satellite images in terms of cloud cover and image quality from the time when the lakes are full of water. The training and testing data were selected with the same distribution in the whole image to make the classifications more accurate. After estimate kappa coefficient and overall accuracy for all kind of supervised and unsupervised methods, the results obtained from the two classification methods of maximum likelihood and support vector machine with linear kernel from Tar and Hovir lakes, the conclusion was that the classification method of support vector machine with linear kernel have better distinguish land and water areas and it is the best method for classifying water basins located in mountainous areas. The amount of water in Tar and Hovir lakes had been increased from 2013 to 2017but in 2018, the water area of both lakes decreased significantly, and in 2019, the largest water area for the lakes was observed and calculated. In 2020, there is no big change in the water area of the two lakes, and from 2020 to 2022, the amount of water in the two lakes is decreasing.

Key words: remote sensing, Landsat 8 satellite, Tar and Hoyer lakes, classification methods.

1. Introduction

Due to the problem of the global water crisis and the importance of land and agricultural products, the studies conducted on water basins and agricultural land and their classification have grown significantly in the last few decades. Satellite images, due to their wide and regular view of the earth's surface, can be a valuable archive for studies of land use changes in the river basin, as well as hydrological studies of the amount of precipitation, changes in the river course, soil type, soil moisture, slope and slope direction of slopes, snow storage. (Level and depth of snow) etc. from all over the globe, it can be used for integrated management and monitoring of water basins as well as creating their hydrological models. By combining these data with information from hydrometric stations, it is possible to check the behavior of water basins in the country and make the necessary predictions before the flood occurs. The surface water changes of Nontasi Tuzla Lake in 2022 in Romania were investigated through satellite images and water indicators. In this research, MADIS and Landsat images were used between 1965 and 2021. 5 indices NDVI, NDWI, MNDWI, WNDWI and WRI were used to check the changes. The results showed that Landsat images were evaluated to have a higher kappa coefficient and overall accuracy than MADIS images due to their high spatial resolution (Şerban, 2022). Also, in 2022, using remote sensing and GIS methods, the coastal wetlands in Burolus Lake in Egypt were investigated. In this study, three Landsat images in 1985, 2000 and 2020 and ISO Data unsupervised classification method were used. The results show that from 1985 to 2020, 44.8% of wetlands have been lost (Keshta, 2022). In 2019, spatial and temporal changes of land use and land cover in Lake Urmia basin were modeled using the combination of automatic cell and Markov chain. In this research, using Landsat images of 1377, 1387 and 1397 and maximum likelihood classification method, the land use map of the studied area was produced. Then, using automatic cell method and Markov chain, the user map of 1407 and 1417 was predicted (Eskandi Doman, 2019). In 2019, during a research, water extraction indicators were evaluated using Landsat satellite images in Gamasiab River, Kermanshah. Landsat images and 5 indices NDWI, MNDWI, AWEI_nsh, AWEI_sh and WRI were used in this research. By evaluating the indexes using two parameters of overall accuracy and kappa coefficient, AWEI index was the best result (Saraskanroud Sayad, 2019). By using remote sensing method and GIS in 2022, the changes of coastline and water level of Al-Razzah Lake in Iraq were evaluated. For this research, 6 Landsat images of 1989, 1999, 2002, 2015, 2019 and 2020 and two classification methods SVM and ISO Data were used. The results showed that the surface water area has decreased by 84.1% and the coastline by 63.4% (Jumaah, 2022) Drought and its effects on vegetation and changes in the water extent of Lake Urmia in 2022 were investigated. For this research, Madis sensor images were used for the period from 2000 to 2020 to calculate NDVI, EVI, NDWI and TVDI indices. One-month and three-month SPI were used to evaluate the indices, and it was concluded that NDVI and NDWI indices are more suitable indices for monitoring the changes in vegetation cover and the area of water basins (Helali, 2022). There is no update research for these lake which affect environment .In this study the use of remote sensing, image classification methods, and researches have been discussed for two important lake for Damavand city from Tehran province. . The purpose of this research is to investigate the changes of water basins by remote sensing method. To choose the best classification method, all unsupervised classification methods including ISO Data and K-Means and supervised classification methods including parallel networks classification, minimum distance from the mean, neural network, Mahalanobis distance, support vector machine, maximum likelihood and spectral angle on Landsat 8 images and select the best method with high resolution for classification then conclude change process in special period of time.

2. Study Area

Tar and Hoyer lakes are mountain lakes located 30 kilometers east of Damavand in a city called Hoyer. These two lakes are located at a distance of 500 meters from each other and these are geological phenomena that were created by the landslide of Zarin Kouh. These two lakes are among the mountain freshwater lakes and are located at an altitude of more than 3000 meters above sea level. Lakes Tar and Huyer are located between 34˚ to 36.5˚ north latitude and 50˚ to 53˚ east longitude. The location of the study area is shown in the figure1.

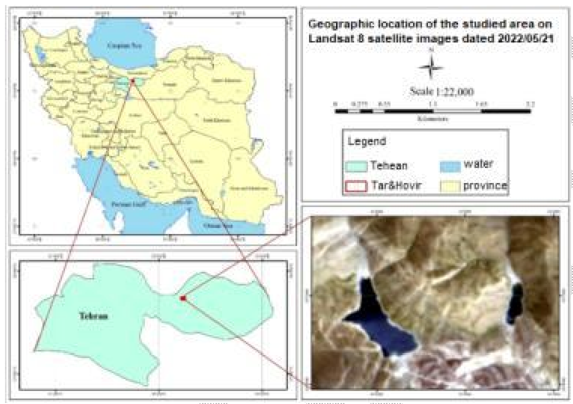
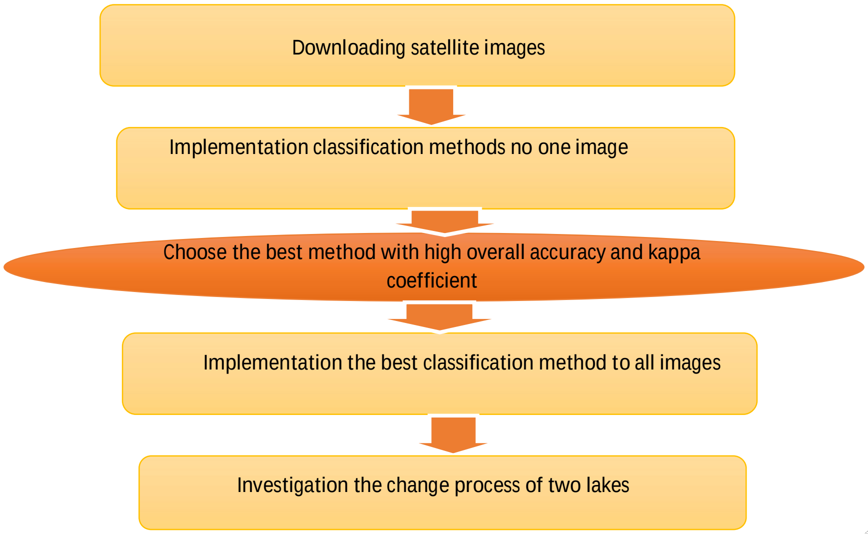


Figure1: Location of the study area

3. Methodology

In this research Landsat8 satellite images According to the topic and purpose of the research from 2013 to 2022, one image for each year, 10 images were downloaded from the USGS server and from the Earth Explorer site. After applying radiometric, atmospheric and geometrics correction in ENVI5.6 software and evaluation supervised and unsupervised methods two method with high overall accuracy and kappa coefficient selected. For regular and complete sampling using the Fishnet command in ArcGIS software, a vector network has been created for the purpose of framing on the polygon of the studied area. Having a vector network, training and testing samples with the same distribution are selected from the entire image. Improvement of the spatial resolution considered, the dimensions of the pixels of the Landsat image is 15 meters, the dimensions of this network are considered 45 x 45 meters. In fact, one sample will be selected for every 9 pixels. The two classes of water and soil considered can be evaluated by using two parameters of general accuracy and Kappa coefficient which is extracted from the error matrix. Research fellow chart is shown by below fellow chart.



Fellow-chart: The study process

3.1. Implementation of classification methods

Assigning pixels with the same DN values or the same spectral behavior to certain classes is called classification.
Classification methods are divided into 3 groups: supervised classification methods, unsupervised classification methods, and object-oriented classification methods (Alavi Panah, 2013).

3.1.1. Supervised classification methods

In this method previous information and knowledge of the phenomena related to the data needed. In this method, the software classifies the rest of the pixels according to specific instructions which divide to several methods like minimum distance, maximum likelihood, mahalanobis, parallel networks, neural network, SVM, SAM. Supervised classification methods that used in this study are introduced.

3.1.1.1. Minimum distance

In this method each pixel belongs to a class that has the smallest distance to the mean class. This type of classifier is mathematically simple and computationally efficient, but it tries to divide the multispectral space without using information such as variances.

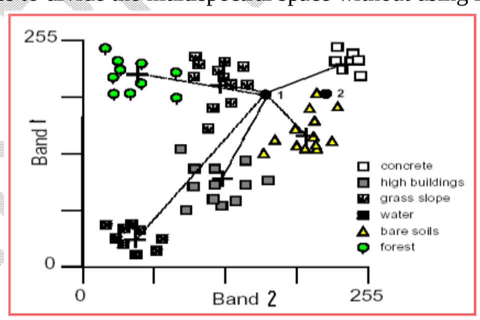


Figure2: Schematic visualization of the minimum distance from the mean classifier

3.1.1.2. Mahalanobis

In this algorithm assumed that the histogram of the bands have a normal distribution. The use of variance and covariance in classification methods are considered when user classes have many changes that lead to the creation of similar variable classes.

3.1.1.3. Parallel networks

According to the spectral range of the sample classes selected on the image, the variance of the spectral values is calculated, and then using the minimum and maximum spectral values of the sample classes in different bands, quadrilaterals are created, which are called parallel networks. After creating parallel grids, the pixels of the image are divided into groups corresponding to the sample areas. The diameter of the error matrix shows the percentage of correctly classified classes and its other cells show the amount of commission error (row of each class in the error matrix) and emission error (column of each class in the error matrix) (seddiqi, 2018).

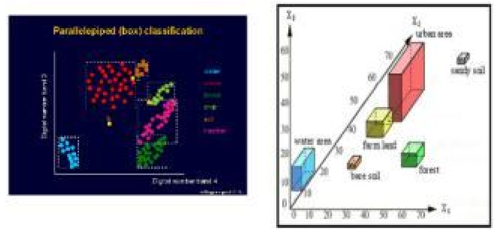


Figure3: Classification of parallel networks

3.1.1.4. Maximum likelihood classification

Maximum likelihood is one of the most accurate and widely used methods between supervised methods. This method evaluation based on variance and covariance of different classes. In the maximum likelihood method, it is assumed that all educational regions have a normal distribution function. After evaluating the probabilities in each class, the pixels are assigned to the classes that have the most similarity, and if the probability values are lower than the threshold, they introduce as unclassified pixels (Alavi Panah, 2013).

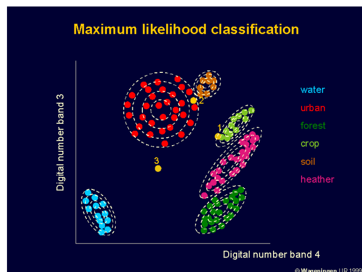


Figure 4: maximum likelihood classification

3.1.1.5 Support vector machines

Support vector machines (SVMs) [8]. An important generalization of SVM is that the number of support vectors is very lower than the training samples in unlike other classifiers (such as decision trees).SVM provides the distances of each of the input support vectors from the optimal cloud plane (Cristianini, 2000).

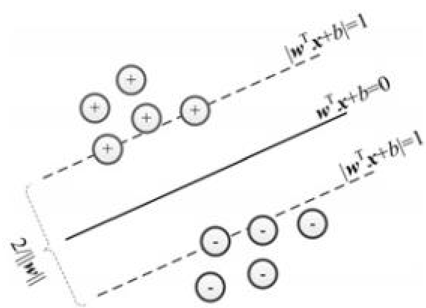


Figure5: A view of binary linear SVM

Binary linear SVM is the simplest, the training sample can be shown in the mathematical form x = {(xi,yi)} im =1; where in an input sample, m is the size of training samples, and a class label. 1 = yi if xi = C1 and -1 = yi if xi = C2. This problem can be converted into a parallel super-plane search problem as:

WTxi + b $\geq$ +1 for di = +1 (positive-plane)

WTxi + b $\leq$ -1 for di = -1 (negative-plane)

Where the vector W is the weight and b is the bias parameter (Burges, 1998) when data was potentially non-linear this method can't be used therefore a functions category, kernel functions (also called kernel) use for Correct separation of classes. The resulting feature space of kernel functions is called Reconstructive Hilbert Kernel Space (RKHS). An inner product in the RKHS space is equal to a mapping of the inner product of the samples in the original low-dimensional space. In other words,

$$K(x_i, x_j) = (\varnothing(x_i), \varnothing(x_j)) \quad (1)$$

For all xi, where Ø is a mapping from the original feature space to a higher dimensional feature space and K is a kernel. Therefore, the kernel can simply replace the inner multiplication in the dual form of the optimization. According to the theory of Mercer (Waske, 2009), every positive semi-definite symmetric function is a kernel. Kernels are linear kernels.

$$K(x_i, x_j) = (x_i, x_j) \quad (2)$$

Polynomial kernel

$$K(x_i, x_j) = (x_i, x_j)^d \quad (3)$$

Where d is the polynomial degree, and Gaussian kernel (also called RBF kernel)

$$K(x_i, x_j) = \exp\left(\frac{|x_i - x_j|^2}{2Q^2}\right) \quad (4)$$

In fact, SVMS is a special kind of kernel method, that linear classifiers facilitated by the kernel trick (Z-H, 2012). Based on Figure 8, by applying the kernel function, samples that need non-linear classification can be easily separated with a page in the new space.

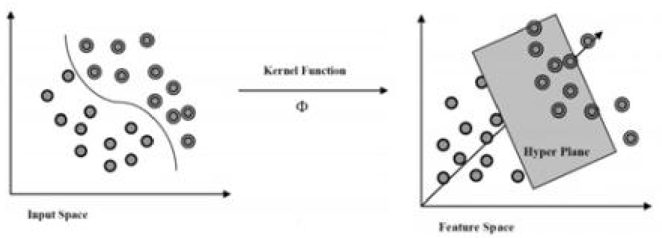


Figure 6: Nonlinear separation using fan kernel SVMs

3.1.1.6. Neural network

These networks configured based on educational examples and network's weight adjusted cost-function for error reduction (Atkinson, 1997).The most popular neuron model is the McCulloch-Pitts model (M-P model) shown in the figure below. In this model, the input signals are first multiplied by the corresponding connection weights, and then the signals are added together and compared with a threshold limit, which is also called neuron bias. If the summed signal is greater than the bias, then the neuron is activated and the output signal is produced by an activation function (also called transfer function) (Z-H, 2012)

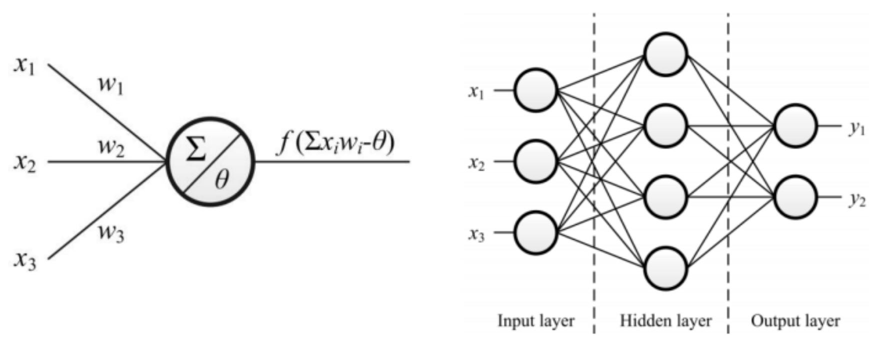


Figure 7: The shape of a simple neuron (left) and an artificial neural network (right) (Amin Ghasemi Esfahalan, 2013)

3.1.1.7. Classification of SAM (Spectral Angular mapper)

The algorithm of this method calculates the similarity between two spectral with the spectral angle between them. In fact, by converting spectral into vectors, the angle between two vectors is calculated in a space with the dimensions of the number of bands. In this method, to calculate the angle, only the direction of the vectors is important, and for this reason, the brightness of the pixel has no effect on its classification. The lower the value of the angle (between 0 and 1), the more accurate the identification will be (Van Der Meer, 2001). If the value of the angle is 1, the whole image is considered. For example, to compare a pixel, the spectrum of the desired pixel is drawn with the spectrum of the same pixel, among the reference spectra on two bands in the same coordinate axis. Then the obtained points are drawn to the origin and the angle between the two resulting lines is considered as the pixel identification angle. To obtain the angle between two vectors, the following relationship (resulting from the spectrum of image point t and reference r) was used (Manolakis, 2003).

$$@ = COS^{-1}\left[\frac{r.t}{|r|.|t|}\right]$$

(5)

It has another exhibition:

$$@ = COS^{-1}\left[\frac{\sum_{i=1}^{nb} t_i r_i}{\left[\sum_{i=1}^{nb} t_i{}^2{}^{1/2}\right]\left[\sum_{i=1}^{nb} r_i{}^2{}^{1/2}\right]}\right]$$

(6)

In this formula:

nb: number of bands, ti: tested spectrum, ri: reference spectrum

The most important advantage of the SAM algorithm is the simplicity of its structure and its quick use to show the spectral similarity between the image spectrum and the reference spectrum. The problem of this classification is not considering the problem of pixels with a mixed spectrum (H, 2006)

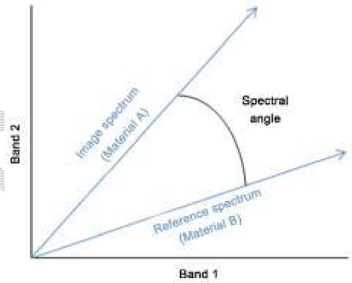


Figure 8: The concept of SAM classification **(Hamza, 2016)**

3.1.2. Unsupervised classification methods

In unsupervised methods, spectral grouping is calculated automatically and only based on the mathematical difference of spectral values. Usually, this classification is used when the user does not have any information about the condition of the studied area.

3.1.2.1. k-means

The k-means clustering algorithm is one of the group of discriminative clustering methods and its computational complexity is equal to $O(^{ndk+1)}$, provided that n is the number of objects, d is the dimension of features, and k is the number of clusters. Also, the time complexity for this algorithm is equal to $O^{(nkdi)}$, which, of course, means the number of iterations of the algorithm to reach the optimal solution.

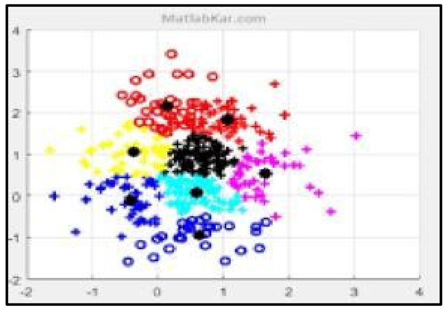


Figure 9: Concept of k-means Algorythm

3.1.2.2. ISO data

The iso-data algorithm is similar to the k-means algorithm, with the difference that the iso-data algorithm provides different numbers of clusters, while the k-means assumes that the number of clusters is known a priori

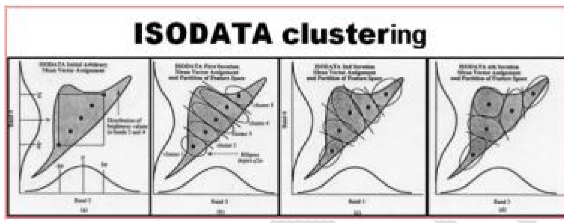


Figure10: Iso data classification

Kappa Coefficient

The kappa coefficient K is a second measure of classification accuracy which incorporates the off-diagonal element as well as diagonal term to give a more robust assessment of accuracy than overall accuracy it is computed as: (R-Jensen, 1996)

$$k = \frac{\sum_{a=1}^{u} \frac{c_{aa}}{Q} - \sum_{a=1}^{U} \frac{c_a c_a}{Q^2}}{1 - \sum_{a=1}^{U} \frac{c_a c_a}{Q^2}}$$

(7)

Where c_a =row sums.

Overall Accuracy

The overall accuracy is obtained from the sum of the main diameter's elements of the error matrix divided by the total number of pixels according to the following equation:

$$\text{Overall Accuracy} = \frac{\sum_{a=1}^{u} c_{aa}}{Q} \times 100\%$$

(8)

Where Q and U is the total number of pixels and classes respectively. The minimum acceptable overall accuracy is 85% (J.Scepan, 1999).

Research results

In this section, unsupervised classification methods including IsoData and K-Means were performed on the Landsat 8 image in 2013 and the classification results are shown in the figures 11 with Overall Accuracy = 75.9704% &Kappa Coefficient = 0.3059.

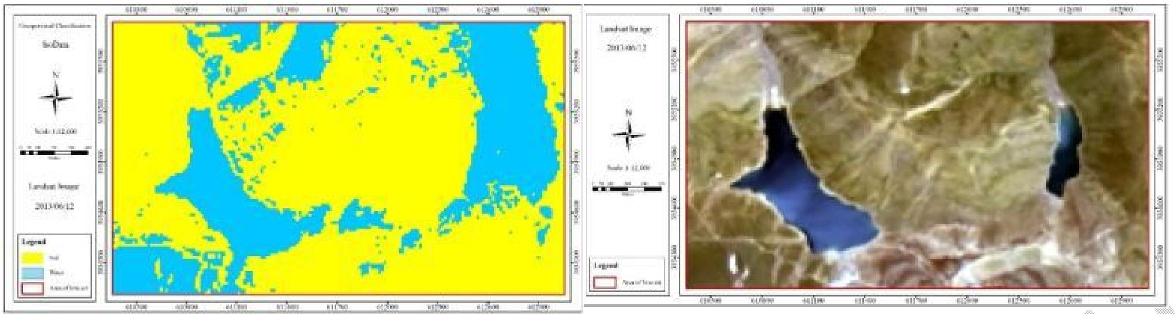


Figure 11: IsoData classification

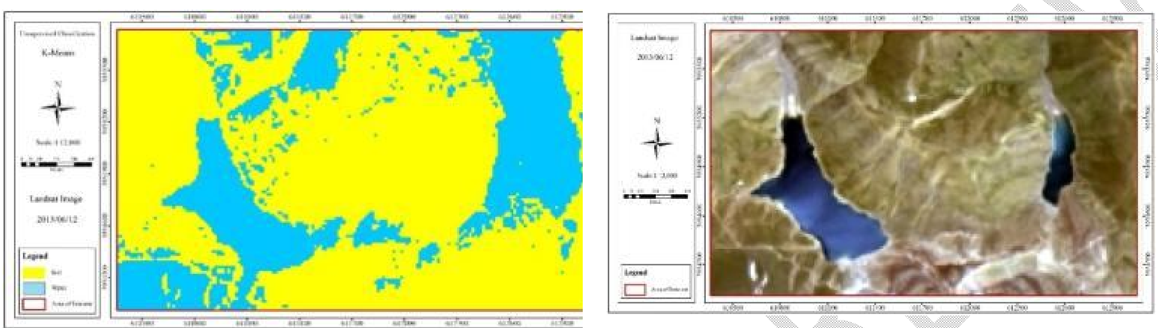


Figure 12: K-means classification

As can see in the figures 12, the unsupervised classification methods of IsoData and K-Means have the same results for the studied area. K-means classification methods not only have a very low overall accuracy= 75.9704% and kappa coefficient= 0.3059, but also failed to separate water and soil areas well, and many areas that are shaded due to the height changes of the area are classified as water. As a result, the unsupervised classification methods are not suitable for the classification of water basins, including Lake Tar and Hovir. In the following, supervised classification methods have been used to classify the image of the studied area. To choose the best classification method, all the supervised classification methods mentioned on the Landsat image in 2013 were performed with the same samples Test samples have been used to calculate the error matrix and two parameters of overall accuracy and Kappa coefficient, in other words, to evaluate the classification method. The soil class is shown in yellow and the water class is shown in blue. In order to see the compliance of the water basin calculated from the classification methods with the area of Tar and Hoyer lakes, the water class has been converted into vector format. Two parameters of overall accuracy and kappa coefficient calculated for each classification method are given at the bottom of the figure corresponding to that classification method. In the following, the results of the supervised classifications of the studied area are given.

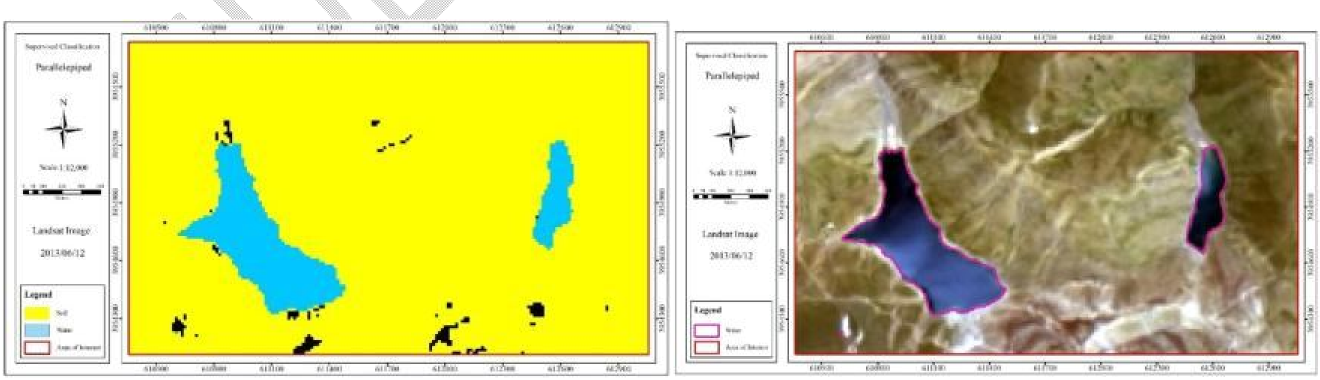


Figure 13: Parallelepiped Classification

Overall Accuracy = 98.8909**%** & Kappa Coefficient = 0.9276

The overall accuracy and Kappa coefficient calculated from the parallel grid classification method is very high, but this classification method could not classify some pixels and these pixels seems as some black areas. Also placed a small area in the water class at the bottom of the left image. This error makes it impossible to use this method to check the changes of the water basin of two lakes because it calculates the area of the water class more.

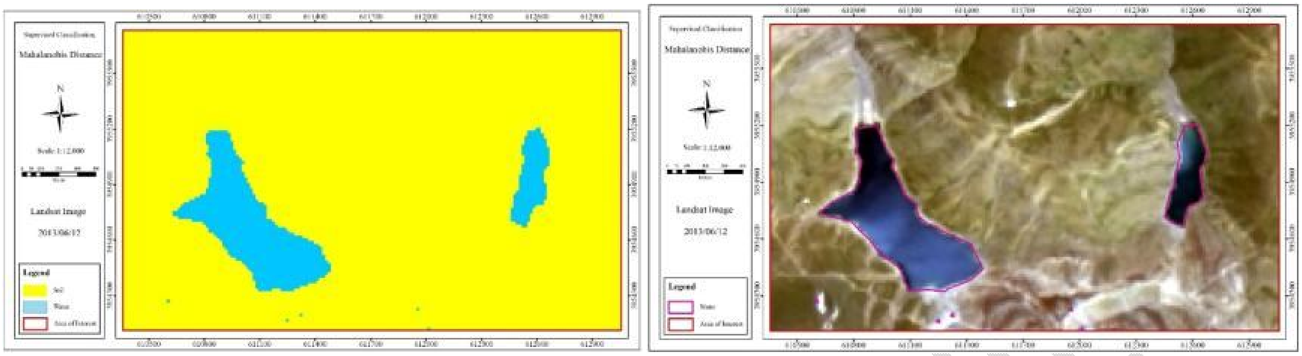


Figure 14: Mahalanobis Distance Classification

Overall Accuracy = 99.2606% & Kappa Coefficient = 0.9484

According to the figure 14, Mahalanobis distance classification has higher overall accuracy and kappa coefficient than parallel grid classification, also this classification method was able to classify all the pixels of the image, but as can be seen in the results, some soil pixels are in the water class. This classification error causes the area of the water class to be calculated more, and cannot be used to calculate the area of the Tar and hovir water basin.

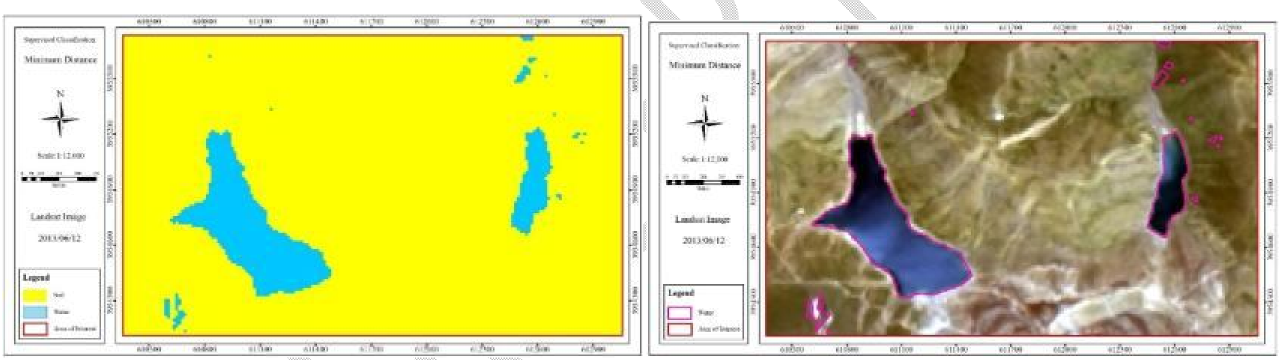


Figure 15: Minimum Distance Classification

Overall Accuracy = 99.2606% & Kappa Coefficient = 0.9505

Minimum distance from the mean has overall accuracy and high kappa coefficient, but it has classified many soil pixels in the water class. Due to the error of calculating the additional and incorrect area of the water class, this classification method cannot be used to check the changes in the water basin of Tar and Hovir.

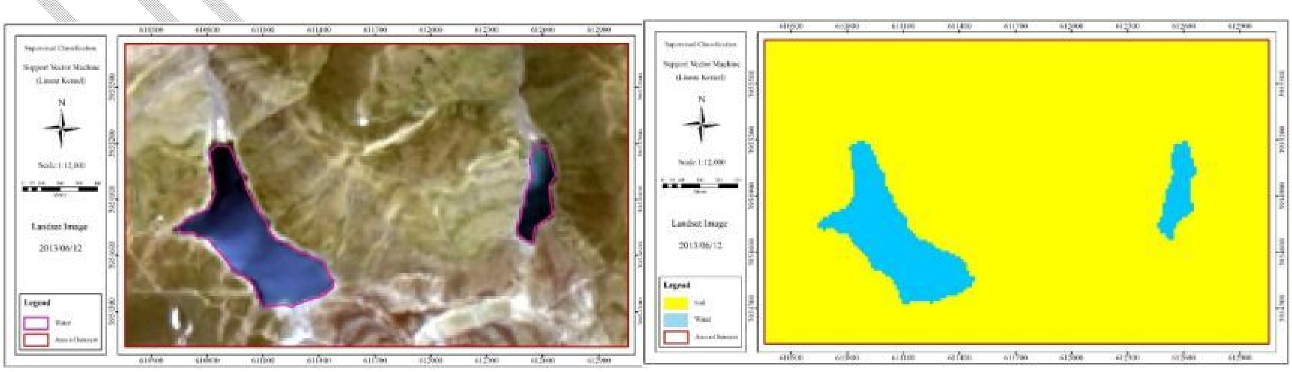


Figure 16: Support Vector Machine classification (Linear Kernel)

Overall Accuracy = 99.2606% & Kappa Coefficient = 0.9472

Support vector machine has 4 kernels. In this research, all kernels have been used for classification. This classification has a high overall accuracy and kappa coefficient, also it was able to correctly separate the water class from the soil class. As a result, it is a suitable method for the classification of the water basin of the study area.

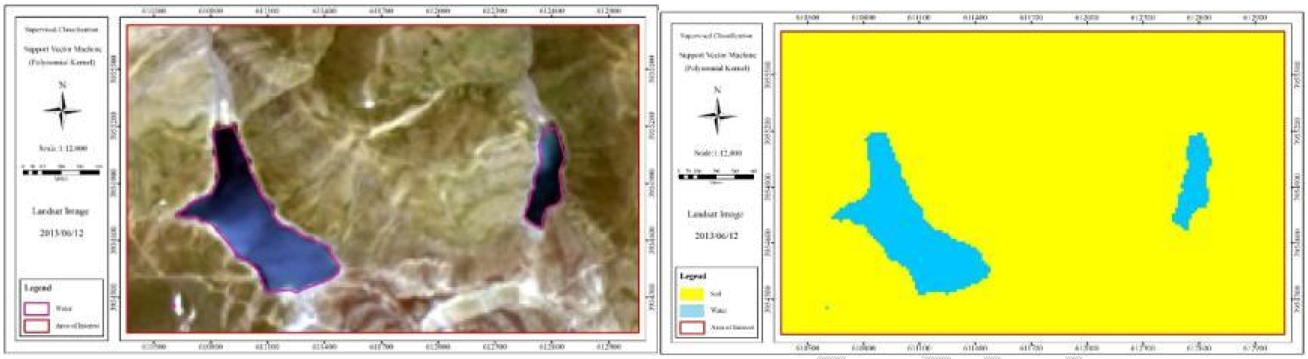


Figure 17: Support Vector Machine Classification (Polynomial Kernel)

Overall Accuracy = 99.4455**%** & Kappa Coefficient = 0.9609

It is obvious that some pixels are classified in the water class. As a result, the polynomial kernel could not separate the water and soil class as well as the linear kernel.

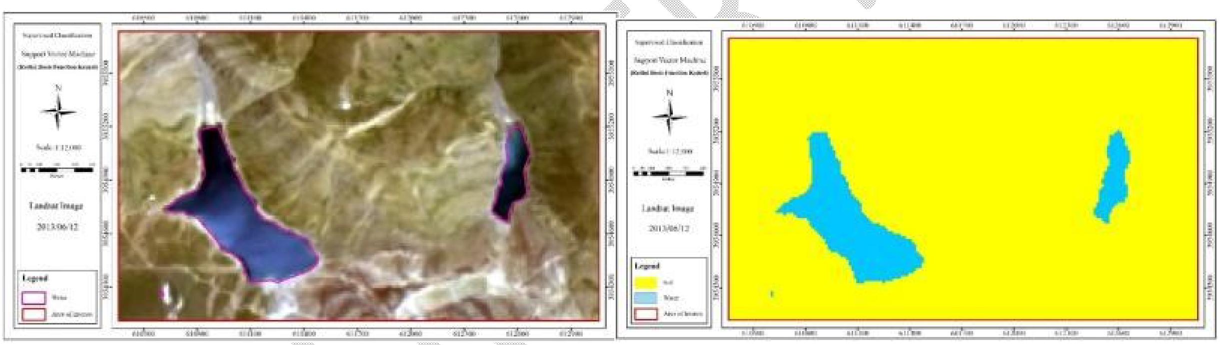


Figure 18: Support Vector Machine Classification (Radial Basis Function Kernel)

Overall Accuracy = 99.4455% & Kappa Coefficient = 0.9609

The result of this classification is similar to polynomial kernel. This kernel also failed to determine well the linear kernel of the water basin of the lakes.

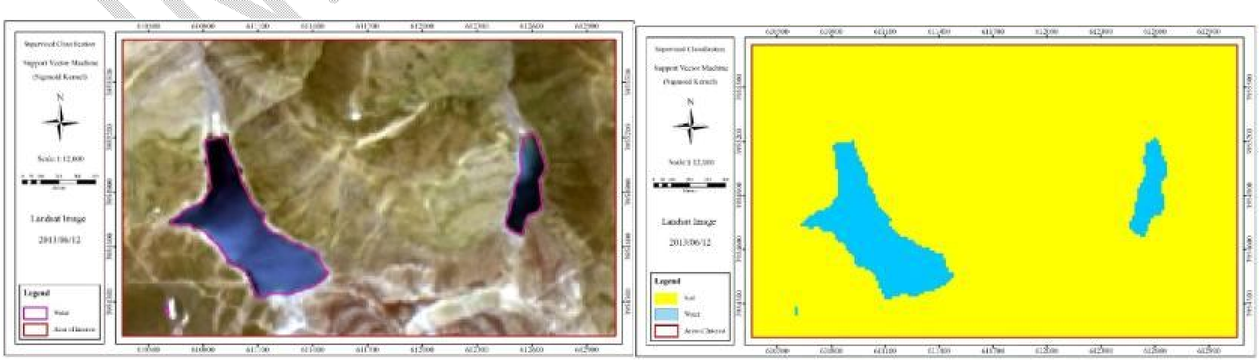


Figure 19: Support Vector Machine Classification (Sigmoid Kernel)

Overall Accuracy = 99.4455**%** & Kappa Coefficient = 0.9609

This classification exhibition is similar to the classification result with two polynomial and radial kernels. In the support vector machine classification method, the linear kernel is more appropriate for investigating the changes in the water basins of research area.

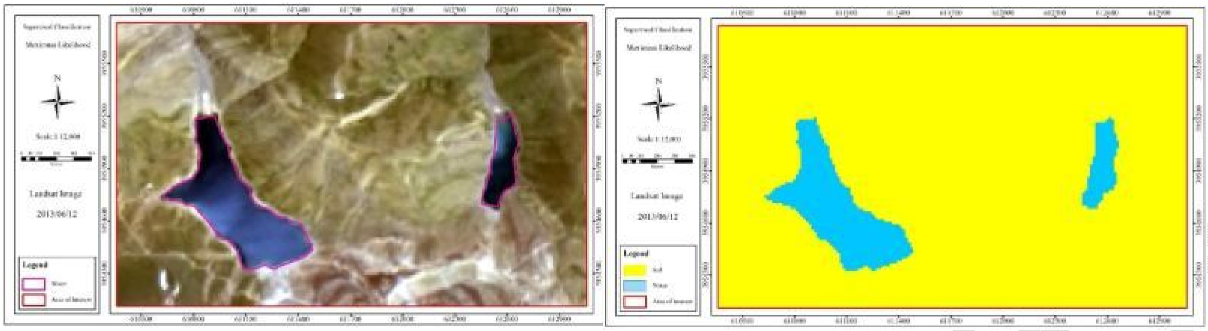


Figure20: Maximum Likelihood Classification

Overall Accuracy = 99.4455% & Kappa Coefficient = 0.9609

To clarifying and comparison with support vector machine classification with linear kernel, it can be seen that the overall accuracy and kappa coefficient of the maximum likelihood method is slightly higher, but both methods have been able to separate the water and soil classes from each other and the lake boundary. As a result, both methods are appropriate for image classification and investigation of water basin of Lake Tar and Hovir.

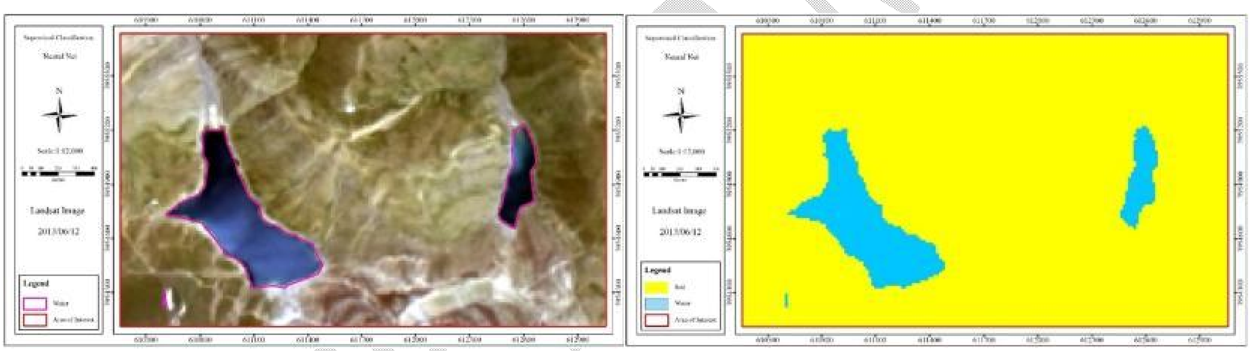


Figure21: Neural Net Classification

Overall Accuracy = 99.8152% & Kappa Coefficient = 0.9872

Results showed that this method has a higher overall accuracy and kappa coefficient than other classification methods of the studied area, but this method has a water class detection error and some soil pixels are in the water class. So, this method is not suitable for classification for the study area of this research.

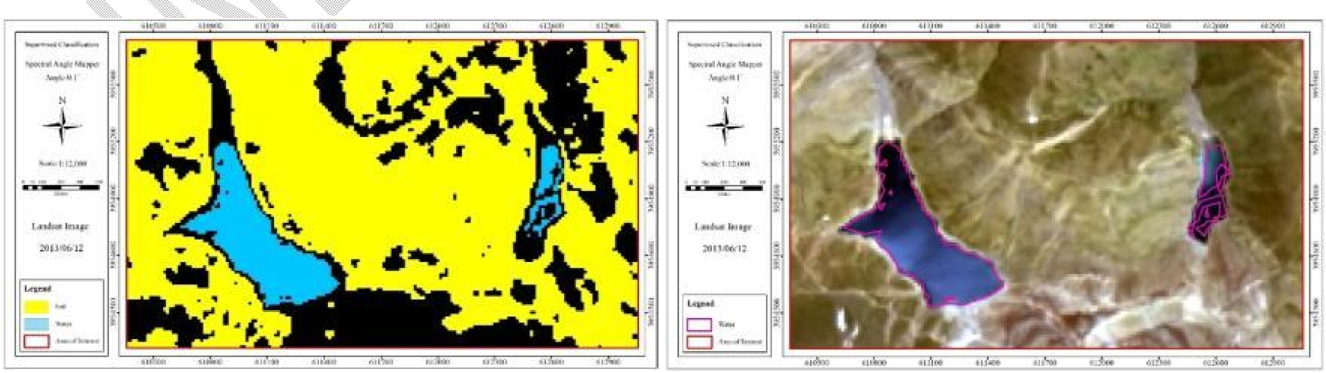


Figure 22: Spectral Angle Mapper Classification (Angle:0.1˚)

Overall Accuracy = 71.1645% & Kappa Coefficient = 0.27

Spectral angle classification method with different angles is used for image classification, and in the first case, the angle of 0.1 degrees (the smallest angle) is introduced to the algorithm. In the first case many pixels of the image are not classified. As a result, this angle is not suitable for the classification of the study area of this research.

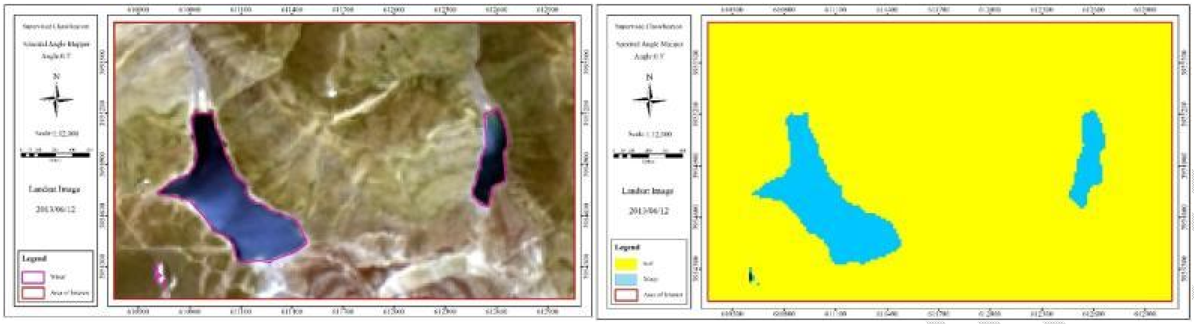


Figure23: Spectral Angle Mapper Classification (Angle:0.5˚)

Overall Accuracy = 99.6303% & Kappa Coefficient = 0.9747

By increasing the value of the angle or in other words, increasing the similarity of the spectrum of training samples with the spectrum of image pixels, many image pixels were classified. Figure showed by applying the highest angle, some pixels were not classified and several pixels were wrongly classified. As a result, this method is not appropriate for the classification of the study area.

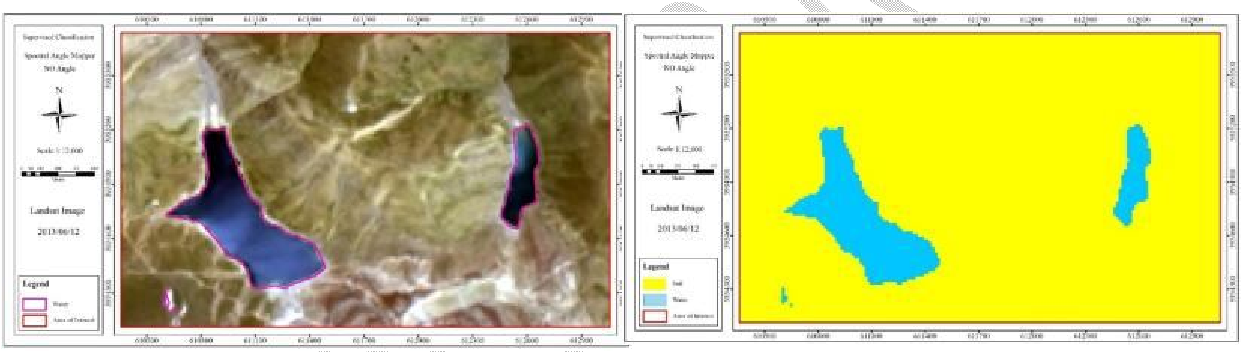
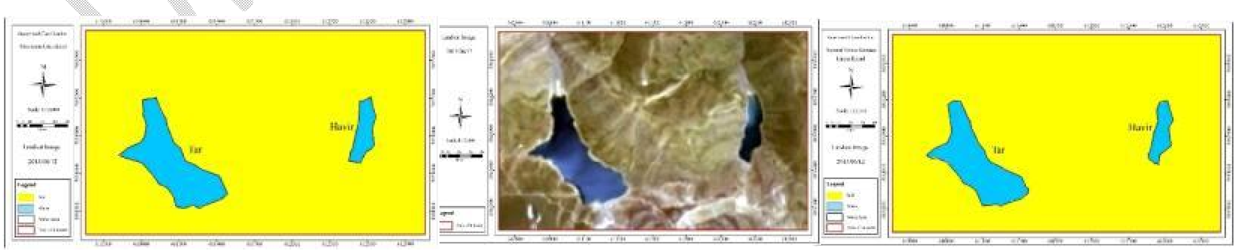


Figure 24: Spectral Angle Mapper Classification (NO Angle)

Overall Accuracy = 99.6303% & Kappa Coefficient = 0.9747

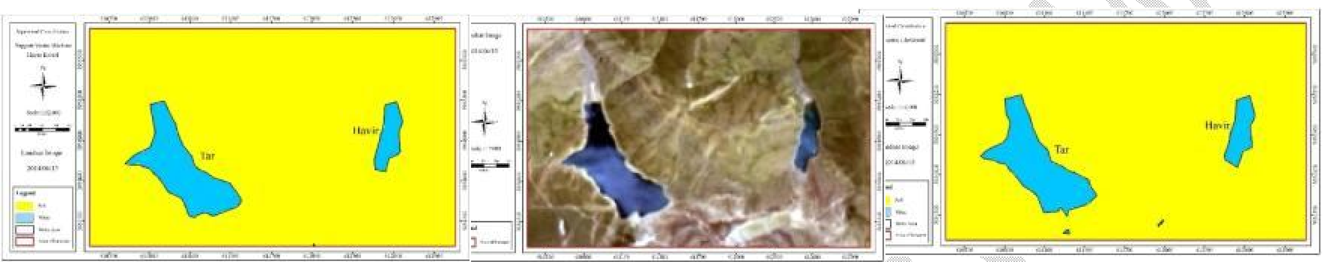
The result of this mode has been improved by introducing the angle in the spectral angle classification method. But as can be seen in the figure above, in this method, several soil pixel classes are classified in the water class, and this method can’t be used for classifying water basins.A ccording to the classification results of maximum likelihood method with overall accuracy of 99.4455% and kappa coefficient of 0.9609 and support vector machine method with linear kernel with overall accuracy of 99.2606% and kappa coefficient of 0.9472, with overall accuracy and high kappa coefficient and good visual results of water class separation from They are soil. So, both methods are suitable for image classification and investigation of water basin of Lake Tar and Hovir.



Maximum Likelihood	SVM(Linear Kernel)
Overall Accuracy = 99.4455%	Overall Accuracy = 99.2606%
Kappa Coefficient = 0.9609	Kappa Coefficient = 0.9472
Tar Area= 27.72 Hec	Tar Area= 26.69 Hec
Hovir Area= 6.32 Hec	Hovir Area= 5.84 Hec

Figure 25: comparison between two superior classification Algorithm

Both of methods were can separate water and land areas with high quality. But as can be seen in the results, the classification of the maximum likelihood compared to the classification of the support vector machine with a linear kernel has calculated an area of 1.03 hectares for Lake Tar and 0.48 hectares for Lake Hovir.



Maximum Likelihood	SVM(Linear Kernel)
Overall Accuracy = 99.6303%	Overall Accuracy = 99.4455%
Kappa Coefficient = 0.9747	Kappa Coefficient = 0.9609
Tar Area= 28.02 Hec	Tar Area= 26.37 Hec
Havir Area= 6.77 Hec	Havir Area= 6.30 Hec

Figure 26: Landsat image2014, middle map, Maximum Likelihood classification and bottom map, SVM (Linear Kernel) classification

The maximum likelihood classificationhas a higher error than the support vector machine classification with linear kernel has classified more soil pixels into the water class. The reason for these errors in the classification is the extreme height changes in the area, which causes shadows or strong light reflection from some areas. To calculate the area of Tar and Hovir lakes. In 2013, the maximum likelihood classification overestimated the area of 1.65 ha for Lake Tar and 0.47 ha for Lake Hoyer compared to support vector machine classification with a linear kernel. As seen in the Landsat 8 image, in 2014 the water level of the two lakes is slightly higher than in 2013.

Maximum Likelihood	SVM(Linear Kernel)
Overall Accuracy = 99.6317%	Overall Accuracy = 99.4475%
Kappa Coefficient = 0.9776	Kappa Coefficient = 0.9660
Tar Area= 30.38 Hec	Tar Area= 29.01 Hec
Havir Area= 8.20 Hec	Havir Area= 7.45 Hec

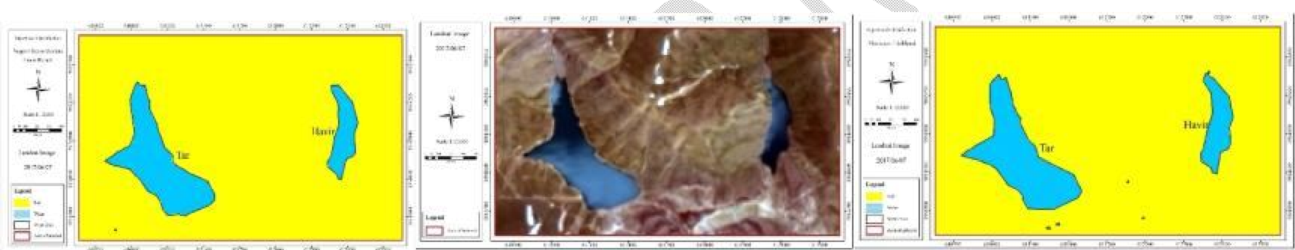
Figure 27: Landsat image in 2015, the middle map is Maximum Likelihood classification and the bottom map is SVM (Linear Kernel) classification.

The errors of the maximum likelihood method are more than the support vector machine with linear kernel, but the overall accuracy and the calculated kappa coefficient of the maximum likelihood classification method are higher.As can be seen in the Landsat images, the water in the Tar and Hovir lakes is higher in 2015 than in 2014 and 2013, and these changes are also seen in the classification results.

Maximum Likelihood	SVM(Linear Kernel)
Overall Accuracy = 99.4475%	Overall Accuracy = 99.6317%
Kappa Coefficient = 0.9678	Kappa Coefficient = 0.9784
Tar Area= 32.95 Hec	Tar Area= 31.53 Hec
Havir Area= 9.06 Hec	Havir Area= 8.53 Hec

Figure 28: Landsat image 2016, the middle map is Maximum Likelihood classification and the bottom map is SVM (Linear Kernel) classification.

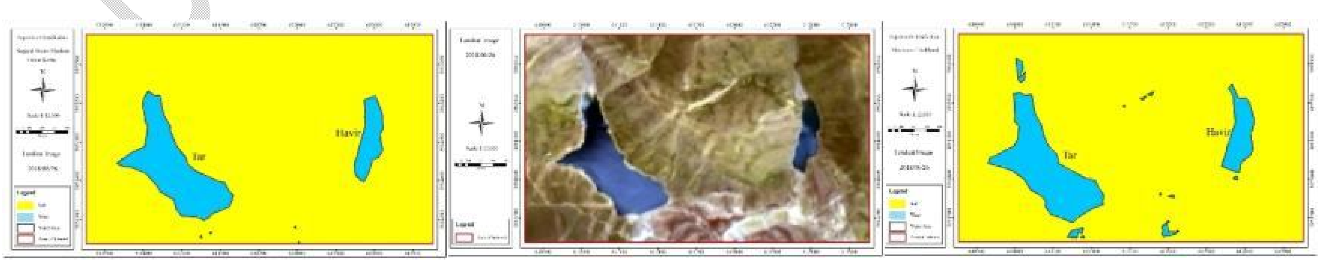
The classification method of the support vector machine with linear kernel has separated the soil and water areas well, but the maximum likelihood classification method has errors and has classified several areas of the soil class into the water class. The maximum likelihood classification compared to the support vector machine classification with linear kernel has calculated the area of 1.42 hectares for Lake Tar and 0.53 hectares for Lake Hovir. The overall accuracy and calculated kappa coefficient of the support vector machine classification method with linear kernel is higher than the maximum likelihood classification method. As a result it is clear that the volume of water had increment.



Maximum Likelihood	SVM(Linear Kernel)
Overall Accuracy = 99.6296%	Overall Accuracy = 99.4444%
Kappa Coefficient = 0.9798	Kappa Coefficient = 0.9689
Tar Area= 35.40 Hec	Tar Area= 33.62 Hec
Havir Area= 10.85 Hec	Havir Area= 10.08 Hec

Figure 29: Landsat image 2017, the middle map is Maximum Likelihood classification and the bottom map is SVM (Linear Kernel) classification.

It can be recognized that the maximum likelihood classification method has more error in classification, but as can be seen, the overall accuracy and calculated kappa coefficient of this method is higher. In 2017, the water of Tar and Hover lakes is much more than the previous years, which can be seen in the results of the area calculated from the classification method. The maximum likelihood classification compared to the support vector machine classification with linear kernel has calculated the area of 1.78 hectares for Lake Tar and 0.77 hectares for Lake Hovir.



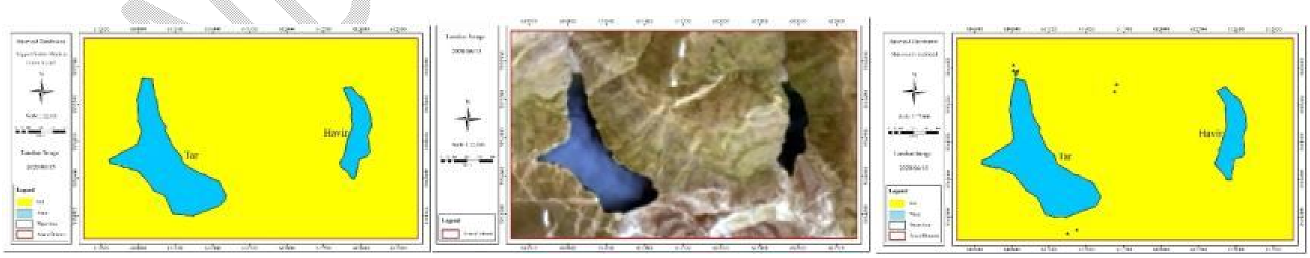
Maximum Likelihood	SVM(Linear Kernel)
Overall Accuracy = 99.0775%	Overall Accuracy = 99.2620%
Kappa Coefficient = 0.9473	Kappa Coefficient = 0.9559
Tar Area= 33.04 Hec	Tar Area= 31.55 Hec
Havir Area= 9.02 Hec	Havir Area= 8.63 Hec

Figure30: Landsat image 2018, the middle map is Maximum Likelihood classification and the bottom map is SVM (Linear Kernel) classification. The support vector machine method with linear kernel has classified smaller and smaller areas of the soil class into the water class. In fact, maximum likelihood classification method has more error in classification. The overall accuracy and calculated kappa coefficient of the support vector machine classification method with linear kernel is higher.The maximum likelihood classification compared to the support vector machine classification with linear kernel has calculated the area of 1.49 hectares for Lake Tar and 0.39 hectares for Lake Hovir. In 2018, the water of Tar and Hover lakes has decreased compared to 2017, which is clearly seen in the results of the area calculated from the classification method.

Maximum Likelihood	SVM(Linear Kernel)
Overall Accuracy = 98.8909%	Overall Accuracy = 98.8909%
Kappa Coefficient = 0.9421	Kappa Coefficient = 0.9412
Tar Area= 37.10 Hec	Tar Area= 35.51 Hec
Havir Area= 11.61 Hec	Havir Area= 10.83 Hec

Figure 31: Landsat image 2019, the middle map is Maximum Likelihood classification and the bottom map is SVM (Linear Kernel) classification.

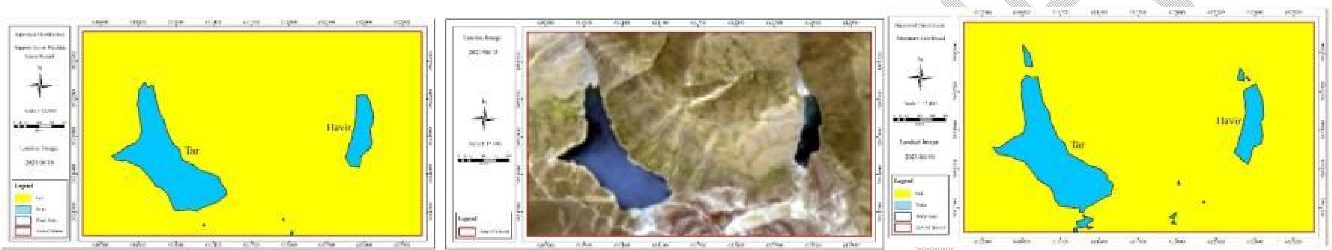
The support vector machine classification method with linear kernel has been able to separate the water and land areas of this image. The overall accuracy and calculated kappa coefficient of both classification methods are equal for this image. The maximum likelihood classification compared to the support vector machine classification with linear kernel has calculated the area of 1.59 hectares for Lake Tar and 0.78 hectares for Lake Hovir. In 2019, the Tar and Hovir lakes were full of water, which can be seen in the results of the area calculated from the classification method.



Maximum Likelihood	SVM(Linear Kernel)
Overall Accuracy = 99.4444%	Overall Accuracy = 99.6296%
Kappa Coefficient = 0.9703	Kappa Coefficient = 0.9801
Tar Area= 37.11 Hec	Tar Area= 36.15 Hec
Havir Area= 10.40 Hec	Havir Area= 10.16 Hec

Figure 32: Landsat image 2020, the middle map is Maximum Likelihood classification and the bottom map is SVM (Linear Kernel) classification.

In this figure, the overall accuracy and calculated kappa coefficient of the support vector machine method with linear kernel is higher than the maximum likelihood classification method. The maximum likelihood classification compared to the support vector machine classification with linear kernel has calculated the area of 0.96 hectares for Lake Tar and 0.24 hectares for Lake Hovir.in the satellite images, the amount of water in Tar and Hoyer lakes in 2020 is shown as in 2019, and it is clear that SVM algorithm has better classification.



Maximum Likelihood	SVM(Linear Kernel)
Overall Accuracy = 99.2606%	Overall Accuracy = 99.2606%
Kappa Coefficient = 0.9589	
Tar Area= 33.82 Hec	Kappa Coefficient = 0.9575
Havir Area= 7.95 Hec	Tar Area= 32.16 Hec
	Havir Area= 7.52 Hec

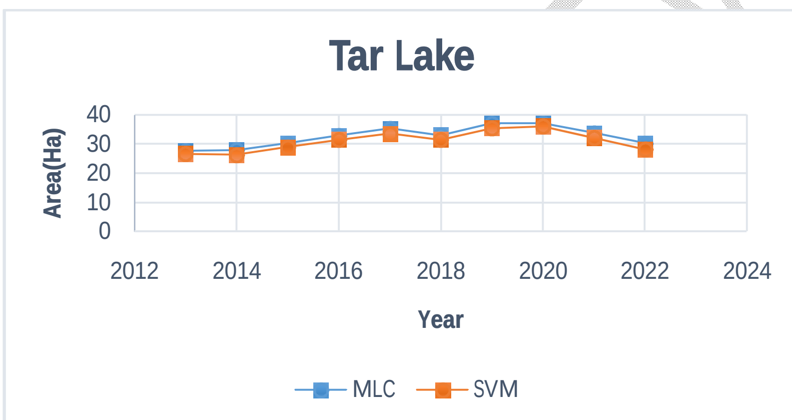
Figure 33: Landsat image 2021, the middle map is Maximum Likelihood classification and the bottom map is SVM (Linear Kernel) classification.

As previous given maps maximum likelihood method has a gross error in classification and has classified large and many areas of the soil class in the water class, but the support vector machine method with a linear kernel has classified fewer and smaller areas of the soil class in the class classified water. The overall accuracy and calculated kappa coefficient of both methods are calculated the same. The maximum likelihood compared to the support vector machine with linear kernel has calculated the area of 1.66 hectares for Lake Tar and 0.43 hectares for Lake Hovir. Decrement compared to 2020, can be observed in the results.

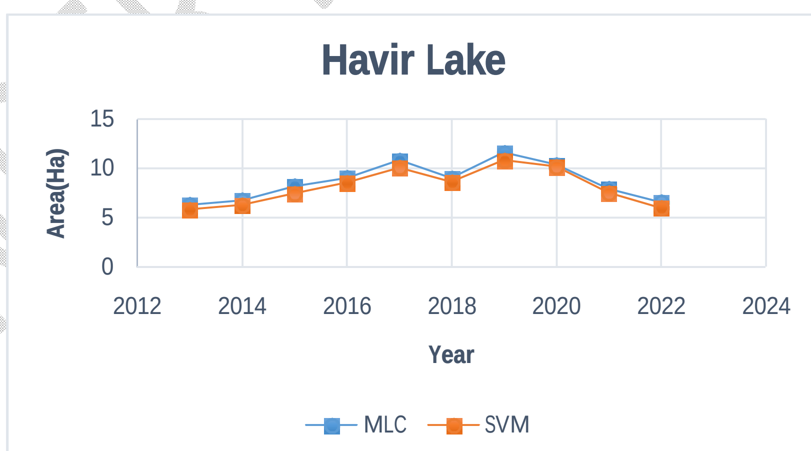
Maximum Likelihood	SVM(Linear Kernel)
Overall Accuracy = 98.8868%	Overall Accuracy = 99.2579%
Kappa Coefficient = 0.9287	Kappa Coefficient = 0.9505
Tar Area= 30.26 Hec	Tar Area= 28.25 Hec
Havir Area= 6.61 Hec	Havir Area= 5.99 Hec

Figure 34: Landsat image 2022, the middle map is Maximum Likelihood classification and the bottom map is SVM (Linear Kernel) classification.

In this image, like the image of 2018 and 2021, the maximum likelihood method could not separate water and land areas well and classified areas of the soil class into the water class, but the support vector machine method with a linear kernel was able to do it well with a low error. Separate water and land areas. The overall accuracy and kappa coefficient calculated for the support vector machine method with linear kernel is higher than the maximum likelihood method.The maximum likelihood classification compared to the support vector machine classification with linear kernel has calculated an area of 2.01 hectares for Lake Tar and 0.62 hectares for Hovir. In 2022, the water of both lakes has decreased compared to the previous years, which is also observed in the results of the area calculated from the classification methods.In the following, a diagram is used to better observe the changes in the area of Tar and Hovir lakes. The change process of each lake is shown separately with two methods of maximum likelihood classification and support vector machine with linear kernel in a graph. The trend of changes in the area of Tar and Hovir lakes in the last 10 years is shown in graphs 1 and 2, respectively.



Graph 1: Changes in the area of Lake Tar in the last 10 years



Graph 2: Changes in the area of Hoyer Lake in the last 10 years

According to graphs 1 and 2, it can be concluded that the water level of the lakes has increment during 2013 to 2017, and the area of Tar and Hovir lakes have increased from 26.69 and 5.84 hectares to 33.62 and 10.08 hectares, respectively. In fact, during 4 years, the amount of water in Tar Lake has increased by 26% and Hoyer Lake by 73%. In 2018, the water area of both lakes has decreased significantly. The amount of water in Lake Tar and Hover has decreased to 31.55 and 8.63 hectares, respectively, or in other words, approximately 7 and 17 percent. In 2019, the largest water area for lakes has been observed and calculated. The amount of water in Lake Tar and Hover has increased to 35.51 and 10.83 hectares, respectively. In fact, during one year, the amount of water in Lake Tar and Hovir has increased by approximately 13 and 26 percent, respectively. In 2020, there will not be many changes in the area of the two lakes. From 2020 to 2022, the water level of two lakes is decreasing. . The amount of water in Lake Tar and Hover has decreased to 28.25 and 5.99 hectares, respectively. In other words, during two years, the amount of water in Lake Tar and Hover has decreased by approximately 28% and 70%, respectively. The precipitation data of this station was prepared from the data request and sale system of the Meteorological Organization. The monthly rainfall of this station in millimeters for the study period of this research is prepared and given in the table below.

Table1: The amount of precipitation in the months of the year in millimeters

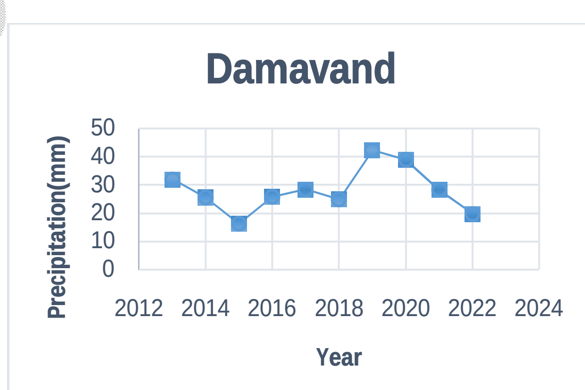
Pre(mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2013	33.7	29.8	36.8	34.1	26.2	2.8	0.4	8	0	7.6	55.3	77.4
2014	16.7	6.9	70.71	36.11	25.5	4.4	5.5	0	0	10	55.82	13.9
2015	24.4	20.5	48.21	2	12.32	0	26.5	0.1	14.71	25.9	13.32	33.7
2016	66.4	4.11	56.61	37.24	32.6	23.91	0	2.1	0.3	0.02	28.91	62
2017	49.21	21.51	69.71	72.6	12.1	0	0.01	0.2	0	20.42	1.3	6.1
2018	22.84	83.81	21.01	89.03	55.71	31	0	3.7	6.2	49.3	45.31	29.31
2019	100	38	95.3	64.5	46	3	3.7	0.9	0	86.7	8.6	17.4
2020	31.1	95.8	37.8	144.3	39.5	0	2.5	3	3	11.7	85.1	36.1
2021	25	48	62.9	4.1	59.1	0.1	0.2	0.1	0	14.1	17.7	37.5
2022	41.2	45.9	45.4	24.8	12.1							

Due to the fact that the two lakes of Tar and Hovir are full of water in the month of June and all the images of this research were selected from this month, the sixth month of the Islamic calendar, which is equal to the third solar month (June), is considered as the base and the average annual rainfall It is calculated and given in the table below.

Table 2: The average amount of rain in the months of Damavand station

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Precipitation (mm)	32.12	25.62	16.42	25.93	28.53	25.04	42.39	39.07	28.38	19.93

In order to better changes observe in the amount of precipitation in individual years and compare it with the trend of changes in the water level of Tar and Hovir lake calculated from the classification methods, the graph of the average amount of rain in the AD months of Damavand station with the data in the above table is given below.



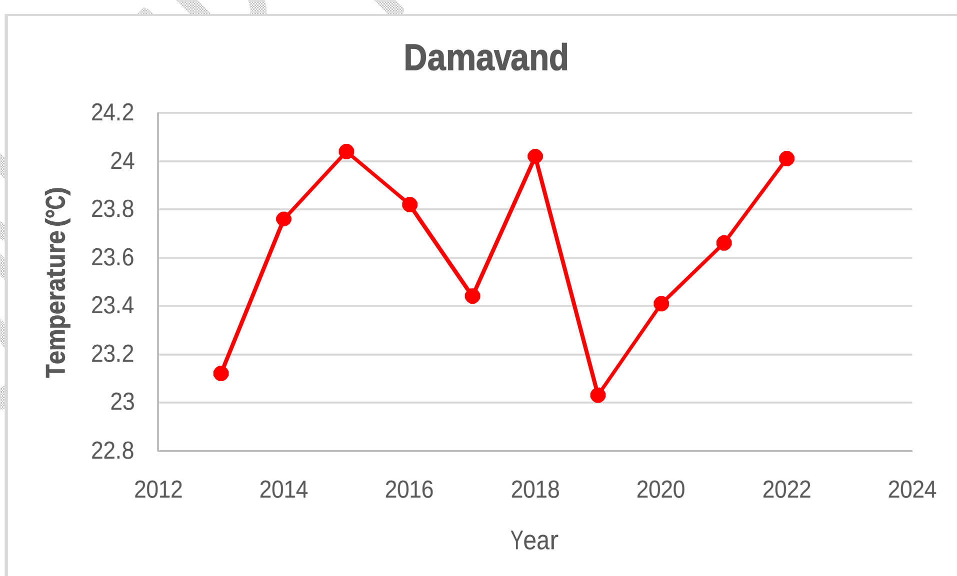
Graph3: The average amount of rain in the months of Damavand station

According to three graphs and comparing the amount of rain and the water level of Tar and Hovir lakes, it can be seen that from 2013 to 2015, the amount of precipitation in the region has decreased, but the water level of the lakes has increased, from 2015 to 2017, the amount of precipitation in the region and the water level of the lakes increased, but in 2018, a sharp decrease in the amount of precipitation and the water level of the lakes was observed. In 2019, the highest amount of precipitation is observed in the region and at the same time, the highest water level of the lakes is observed. From 2019 to 2022, with the decrease in the amount of precipitation in the region, the water level of the lakes has also decreased. The only difference and inconsistency between the amount of precipitation in the region and the water level of the lakes can be seen in the period from 2013 to 2015. Considering that the snow accumulates on the mountains in the winter and starts to melt from the beginning of spring with the increase in air temperature. And also considering that all the images of this research were selected from the month of June, the average temperature of the first 3 months of each year (4th, 5th and 6th months) in order to check the lake water level from the data request and sales system of the Meteorological Organization for the meteorological station. Damavand is prepared. The average temperature of the first 3 months of each year at Damavand station in Celsius for the period studied in this research is prepared and listed in the table below.

Table 3: The average temperature of the 4th, 5th and 6th months of each year at Damavand station

Year	Temperature
2013	23.12
2014	23.76
2015	24.04
2016	23.82
2017	23.44
2018	24.02
2019	23.03
2020	23.41
2021	23.66
2022	24.01

In order to see the temperature changes in the years and compare with the changes in the water level of Tar and Hover lake which is calculated from the classification methods, the graph of the average temperature of the months of the year (the average temperature of the first 3 months of each year) of Damavand station is given below.



Graph4: The average temperature of the 4th, 5th and 6th months of each year at Damavand station

According to the four graphs it can be seen that the temperature changes are more and better than the Precipitation corresponds to the water level of Tar and Havir lakes. With the increase in temperature and the melting of the snow in the mountains around two lakes, Tar and Hovir, the water level of the two lakes has increased, and with the decrease in temperature, the water level of the two lakes has decreased. In general, it can be concluded that the level of water in Tar and Hovir lakes is highly dependent on the temperature of the region, and the maximum likelihood classification method and support vector machine with linear kernel have the most correlation and successfully.

Conclusion

Due to the problem of the global water crisis and the importance of agricultural products, the studies conducted on water basins and agricultural land and their classification have grown significantly in the last few decades. Advances in this field have enabled researchers to examine existing problems from different perspectives. Considering the importance of this issue and the complexities in this field, we still need up-to-date studies and more accurate methods for water and soil management. Two maximum likelihood classification methods with an overall accuracy of 99.4455% and a Kappa coefficient of 0.9609 and a support vector machine method with a linear kernel with an overall accuracy of 99.2606% and a Kappa coefficient of 0.9472 were selected to investigate the changes in two lakes. Also, the classification results should also be checked. Level of Tar and Hovir‘s water depends on the amount of precipitation and temperature in the region that classified in graphs and charts in this study.By observing the results obtained from the two methods of maximum likelihood classification and support vector machine with linear kernel for 10 Landsat images of Tar and Hover lakes, we can sort the conclusion :

1. The maximum likelihood classification method has not been able to separate water and land areas well in many images.

2. The support vector machine classification method with linear kernel has been more successful than the maximum likelihood method and have capability for separate water and land areas in many images. In other words, the maximum likelihood classification method has worked better and more successfully in classifying all images.

3. According to graphs 1 and 2, both classification methods were able to show the changes of Tar and Hover lakes well, but as can be seen, although the classification errors of dry areas were not used to calculate the area of the lakes, but in all Over the years, the maximum likelihood classification method has calculated the average area of Lake Tar to be 1.5 hectares and the area of Hovir Lake to be 0.5 hectares more.

4. The amount of water in the lakes has been increasing from 2013 to 2017, but in 2018, the water area of both lakes has decreased significantly. In 2019, the largest water area for lakes has been observed and calculated. In 2020, haven’t obvious deference in the water area of two lakes. From 2020 to 2022, the water level of two lakes is decreasing.

5. Although the classification method of support vector machine with linear kernel has performed better than maximum likelihood classification, but in 2014, 2015 and 2017, two parameters of overall accuracy and kappa coefficient show a lower number. As a result, in order to choose a better classification method, apart from the two parameters of overall accuracy and Kappa coefficient, the classification results should also be observed and analyzed.

6. Due to the less error and better classification of the support vector machine method with linear kernel, the area calculated from this classification method can be selected and used as a basis for further work.

7. Research is mountainous and has many elevation changes, and elevation changes cause a lot of shadow and light reflection in the image, the support vector machine classification method with linear kernel has been able to better distinguish land and water areas from also separate. As a result, it is a more appropriate method for classifying water basins located in mountainous areas. By observing the changes in the water level of Tar and Hover Lakes using satellite images and classification methods and comparing it with the amount of rain and temperature in the region, it can be concluded that the amount of water in Tar and Hover Lake, in addition to the internal springs, also depends on the amount of rainfall and temperature.

Future challenges

Based on what was obtained in this research, it is better to pay attention to the following things in future research:

1- Tar and Hover Lakes are located in the mountainous region, and mountainous regions have different elevation changes, and many factors affect the image in these regions, as a result, it is better to examine all the classification methods for all the lakes located in different regions. To choose the best method according to the environmental factors of the lake and the effects they have on the image.

2- The pixel size of Landsat image is 15 meters in the best case, and to see the exact border of water basins, it is better to use images with high spatial resolution so that the classifications can be done more accurately. Because the spatial resolution has a great impact on the classification accuracy.

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