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Evaluating Climate Change and Anthropogenic Effects on Inducing Salt Storms & Aerosol Hazards Risk in Urmia Lake Basin

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Abstract: Urmia Lake is the largest inland wetland in Iran, which is shrinking. The gradual drying of Lake Urmia has been both a national and international issue for several years. In recent decades, climate change, dam constructions, unsustainable industrial development and excess exploitation of groundwater for agriculture have been the main cause of drying of Lake Urmia. It has been proven that in the case of lakes drying up, this change has an effect on the global climate. Considering the salinity of Urmia Lake and direction of the wind (principally in a W-E trending), the eastern coastal area of Urmia Lake is seriously in danger of salt intrusion into the soil and underground water that can totally affect the lives of the local population. It also endangers the existence of fauna and flora. This paper attempts to clarify the danger of drying Urmia Lake and salt dumping at the beds of lake and determine the effective parameters, using GIS® and ENVI software. Among the causes of Urmia lake dryness, the dam constructions have been identified as the main reason that has more drastic effects on Urmia Lake.

Keywords: Aeolian processes; Salt storm; Urmia Lake; Necessary Action plan; Iran.

1. Introduction:

Urmia Lake is one of the human natural heritage, one of the most uniquely significant landscape in environment. Urmia Lake has been experiencing a serious ecological crisis over the past decade. Lake water is saturated with salts to the point where salt crystals form on the lake surface year round (Valiallahi J. 2017).

Saline water intrusion occurs in many countries worldwide. It has influenced the local agriculture, the quality of fresh water, fields, the ecology of the regions and the local economy. (QIU Han et al., 1997; Williams, 2010).

Air pollutants and dust phenomenon as one of the major environmental disasters - climate known, consistently with other atmospheric pollutants can be measured(Mostofie et al., 2014). Similar environmental impacts are possible to occur in Urmia Lake, however, with different intensities and extent. It is noteworthy to express that saline water intrusion takes place by the power of hurricanes that can carry enormous amounts of water with high concentrations of salt throughout the coastlines. “Based on surveys, at least about five billion tons of salt have been deposited in the bed of Lake Urmia (especially in the northern half of the lake). The thickness of salt in the deep areas of the north of the lake is estimated at about four meters” (Manaffar R, Zare S., N. Agh, et al. 2011).

Thus, Urmia Lake is going to completely shrink in the near future. Now, the question is that how can the shrinkage of the lake progress the intrusion of salt in the soil and ground-water?

1-1 Site information

Urmia Lake is located in the West Azerbaijan province, northwest of Iran. Since ancient times, it has been very important economic, cultural and environmental values (Malian A., Mohamadi A., Valiallahi J. 2017).

Urmia Lake is the greatest permanent lake of West Asia and it is the second saline water lake in the world after the Dead Sea. "The basin of Urmia Lake makes up 3.15% of Iran's total territory and includes 7% of the total surface water in Iran. There are 14 permanent rivers, 7 seasonal rivers and 39 episodic ones in Urmia Lake basin. The annual average precipitation of the lake basin is between 200 and 300 mm The air temperature usually ranges between zero and 20° C in winter, and up to 40° C in summer (Eimanifar et al., 2006).

Urmia Lake basin has a unique combination of a large area (about 6100 km^2) with a variety of animals (212 species of birds, 41 reptiles, 7 amphibians, 27 species of mammals, and 26 fish types) together with diverse plants (546 species recorded) existing in the wetland basin (Babayan et al., 2003).

The total surface area of the lake was between 4750 km^2 and 6100 km^2 depending on the evaporation and water influx, but in recent decades the surface area decreased to about 2/3 of its primordial amount (Eimanifar et al., 2006). The important elements causing the lake drying up are: the decrease of the average annual precipitation, the increase of the local and global temperature, increasing of irrigation by using river waters for agricultural aims, increasing demand for food due to intense population growth and extracting fresh water from wells in the lake basin and "the construction of many dams" (Hassanzadeh et al., 2012; Sima and Tajrishy, 2013; Marjani and Jamali, 2014). The above-mentioned elements are essential factors leading to the drying up of Urmia Lake. But what will happen when the lake becomes completely dry up?

2. Material and methods:

To detect changes in the region, the information of remote sensing sources such as photographic images, and available GIS information and maps were provided. The data on historical constriction of dams, the statistical information of the studied area population, and data on agricultural expansion in the aria was obtained from related institution or obtained from formal reports of local administrations.

The integration of the spatial information system and the measurement of the data provides valuable information for detecting the type of variation and the spatial distribution and changes in the different classes of land cover.

By plotting the rose diagrams for winds of the Urmia Lake basin, the areas in danger has been identified. To complete the data basis of this work, the most recent (2004-2014) records of the winds were collected from three meteorological sites including Urmia, Mahabad and Miandoab cities all located in the western basin of the lake. The collected data were imported into the WRPLOT view software. The obtained plots were overlapped on the geographic map. The maps were extracted from Digital Elevation Models (DEM) of Iran from 30 meters that were obtained from the National Cartographic Center (NCC), using GIS version 10.3.

To analyze, data related to Urmia Lake were first collected. Data from the years 1955, 1985, 2007, and 2014 were used to evaluate the process of drying the Urmia Lake and detect changes in its perimeter environment during the past half-century. In this regard, geometric and radiometric corrections were made on images. Then, using aerial photographs of 1955, based on the principles of photo interpretation and with the help of ground facts, a map of land use in the area of Lake Urmia was extracted. In the next step, to evaluate the changes in the lake boundary, Landsat satellite images of 1985, 2007, and 2014 were used and the lake range and ground Coverings were extracted (Fig. 1-7).

To evaluate the influence of the lake on the surrounding environment, the satellite images are used. The images are classified by ENVI 4.7. For this study, three predominantly cloud-free Landsat TM images of the Urmia Lake (path 168, row 34) were selected (Table 1). The Landsat images covering almost the entire eastern basin of Urmia Lake (the study area).

The satellite images were geometrically corrected using topographic maps (scale 1:100000) considering the maximum neighborhood correction, then radiometric and atmospheric corrections (Chander and Markham, 2003) were operated by utilizing the ENVI 4.7 for each period of study (2000, 2010, 2014). Then the unsupervised classification and ISO DATA method were used for image classification.

The classified images were corrected using classified geological maps that were obtained from the National Cartographic Center (NCC). To achieve the study aims, five land use/cover classes are defined to include wastelands which are dry in parts of the lake, husbandry, water body, mountains and barren land in ENVI 4.7. Then by applying NDVI (normalized difference vegetation index) on images, a vegetation-covered map was obtained that shows the expansion of the vegetation area (Fig. 3).

The classification validation using standard Kappa has been evaluated for Land use images and field observations. Standard "Kappa (Cohen's Kappa, 1960) is an index that have the following properties:

If classification is perfect, then Kappa = 1; if observed proportion correct is greater than expected proportion correct due to chance, then Kappa > 0; if observed proportion correct is equal to expected proportion correct due to chance, then Kappa = 0; and if observed proportion correct is less than expected proportion correct due to chance, then Kappa < 0 (Bayes Ahmed, et al, 2013).

But Pontius (2000, 2002) criticized standard Kappa. He tried to prove that standard Kappa is not giving appropriate information.

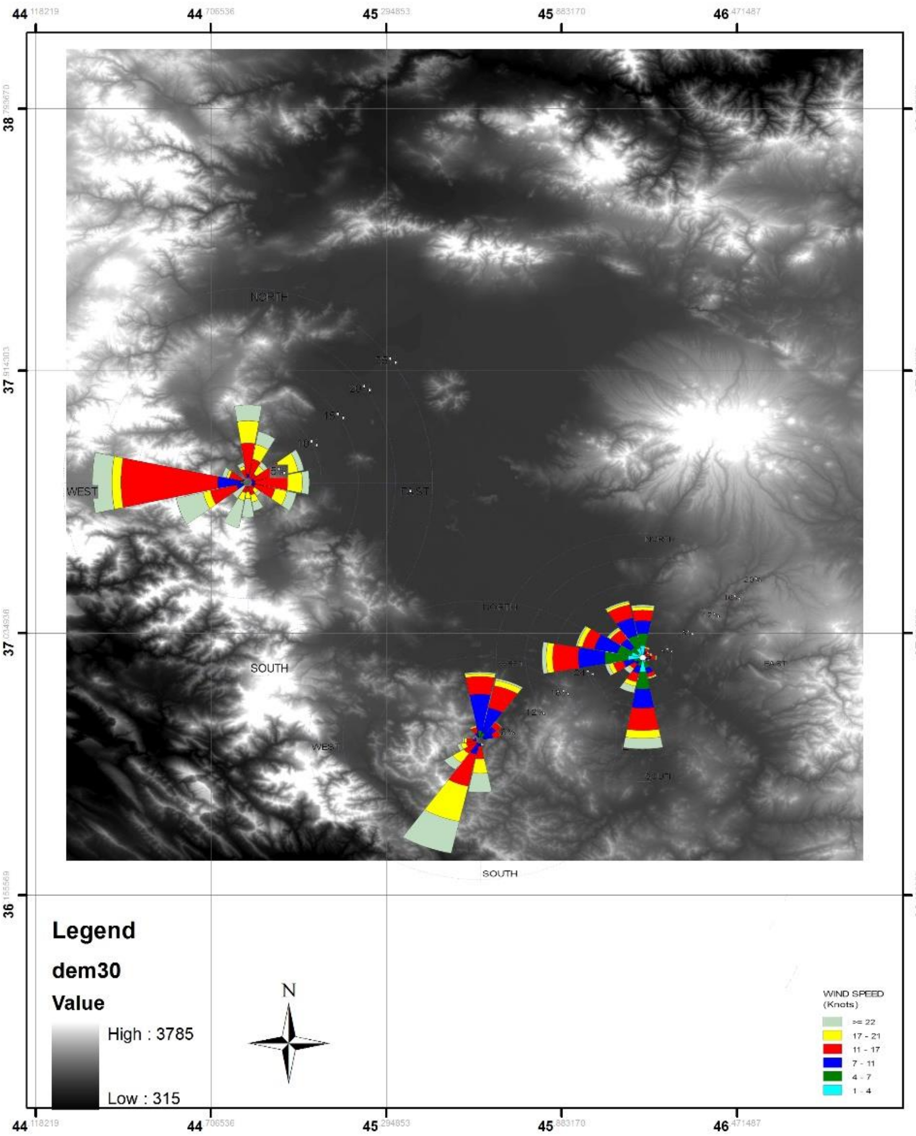


Fig. 1. Urmia Lake Basin, Wind Rose Plots. This plot shows wind direction in three meteorological sites including Urmia, Mahabad and Miandoab. Wind data recorded from 2004 to 2013.

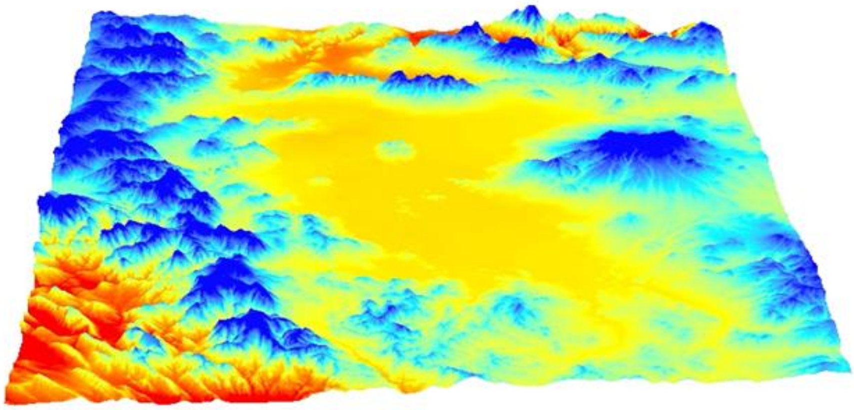


Fig. 2. Classification of Urmia Lake basin according to the altitude. The yellow area includes Urmia Lake bed and other areas that have the same altitude as the lake. The maps extracted from DEM of Iran 30 meters that obtained from the National Cartographic Center (NCC).

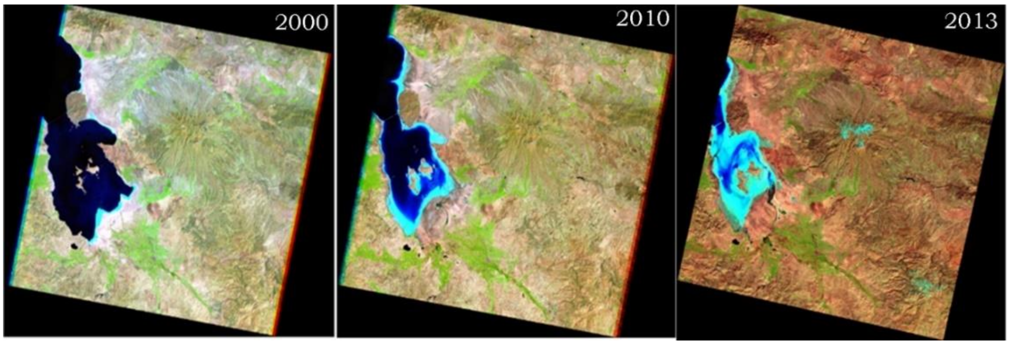
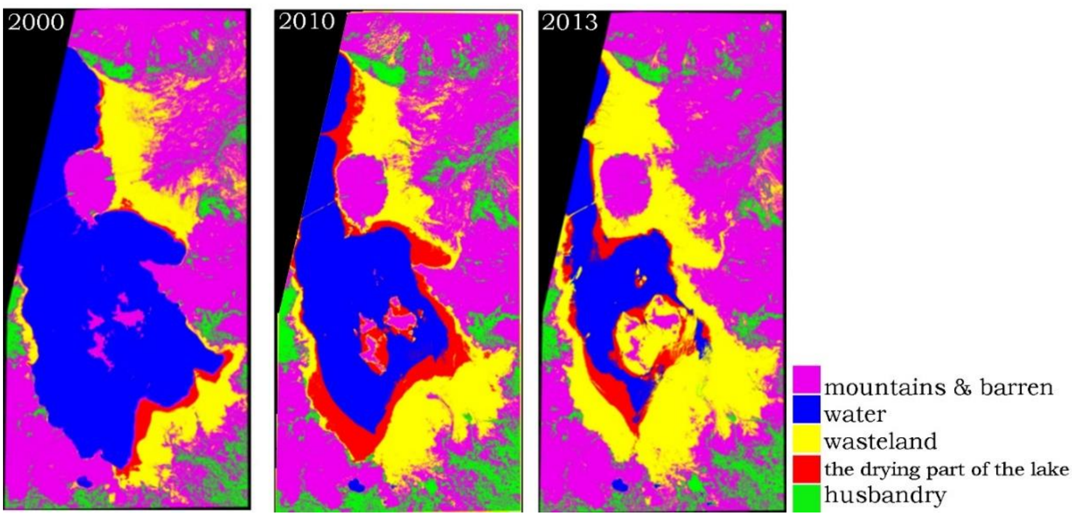


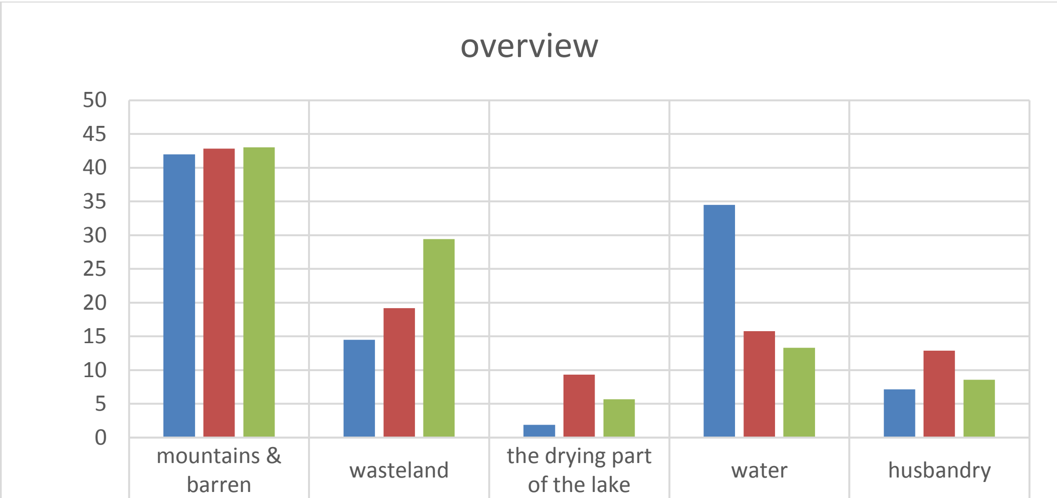
Fig. 3. The Urmia Lake's Landsat images. The progress of shrinking the lake is observed during the years 2000 (left), 2010 (middle) and 2013 (right).

Fig. 4. The NDVI (Normalized Difference Vegetation Index) class. The images show the extension of vegetation in the years 2000 (left), 2010 (middle) and 2013 (right). The area that covered by vegetation is shown in white. These vegetation areas use water that should run into the



Lake.

Fig. 5. The classified images of Urmia Lake showing the progress of wasteland during the years of 2000 (left), 2010 (middle) and 2013 (right). The images are classified in 5 land types, shown by different color in the legend. The expanded wasteland (yellow area) can be detected in eastern parts of the lake.



	mountains & barren	wasteland	the drying part of the lake	water	husbandry
2000	41.984	14.475	1.886	34.505	7.147
2010	42.818	19.192	9.309	15.78	12.899
2013	43.02	29.416	5.702	13.3	8.562

Fig. 6. Comparison of variations in five land use/cover classes of the Urmia Lake Basin during 13 years (2000-2013). The revolutionized change is observed by an inverse correlation between water evaporation and wasteland expansion.

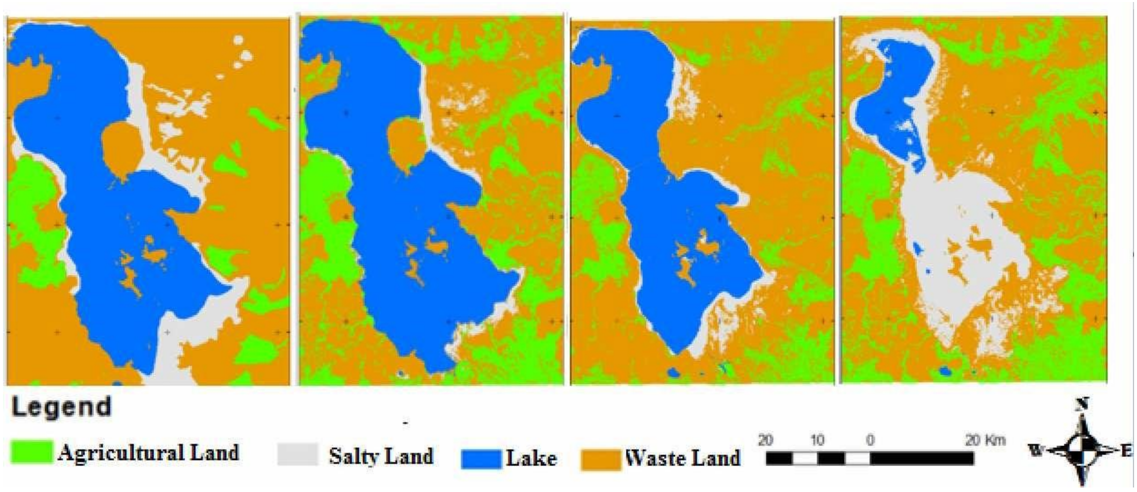


Fig. 7. User map / Groundcover. From left to right, 1955, 1985, 2007, 2014 (prepared by the authors according to the results of the research). (Malian A., Mohamadi A., Valiallahi J. 2017.)

However, that concept has not yet been recognized globally. The land-use modelers widely use Kappa, as a simple index to estimate the accuracy of base maps and for map comparison purposes (Pontius, R.G., Jr. 2000, 2002, Kitada, K.; Fukuyama, 2012). Therefore, still Kappa is a very popular and well recognized map comparison index (Long, J.B.; Giri, C. 2011).

Figure 7 show land use in Urmia Lake basin, from left to right, 1955, 1985, 2007, 2014. The land use image was prepared by the authors according to the results of the research, then the data classification algorithm was applied to the data and the results were extracted. At a later stage, these results in the information medium A place to be visited. The *Overall accuracy* of the ranking was estimated at 93% and the *Kappa* coefficient was 09%, indicating the acceptable reliability of the implemented method. This stage of historical data related to the use of land in the area of Lake Urmia (Malian A., Mohamadi A., Valiallahi J. 2017).

3. Results:

For revealing the cases of the Urmia Lake drying process, in the past, more attention has been paid to detecting changes in coastal lines and not to reveal the perimeter environment and the interactive effects of its actual factors. Study of changes in the range of Lake Urmia indicate that with the comparison of 1955 and 2014, the area of the Urmia River fell by about 80%, and during this period, the area of saline increased by 70%. The decreasing trend of the area of the Urmia river has intensified in the last seven years so that in the half-century the area of the lake decreased by about 362100 hectares, while during the last seven years it has decreased by 300,600 hectares, indicating a sharp decrease in the area of the lake in recent years. In other words, the trend of change in the last ten years is about 6 times the change in the area of the Urmia wetland during the past half-century. Also, due to the changes that have been made during the past 50 years, 150300 hectares of agricultural land have been added, while the increase in agricultural land in the last 7 years is 39700 hectares, which means that agricultural land development has doubled in comparison with the past 50 years. Therefore, economic activities in recent years have been a factor influencing the extraction of groundwater and reducing the supply of surface water in Urmia sxc65xc45rLake. In addition, during the last 50 years more than 50 dam had been constructed in Urmia Lake basin and more than 40 dam are to be constructed during the further years. The construction of dams in the Urmia lake basin has been an exacerbating factor in reducing the water, which has led to its gradual death.

The importance of severe sedimentation of salt and river salts in the Urmia basin, especially in the deep regions, that has become the biggest barrier to lake recovery today and furcating of the wind effects and direction is illuminated in this paper. If the drying process of Urmia Lake will be continued, considering the concentration of the wind speed and salt in Urmia Lake and a common west-east direction of the wind in the region, at the next furthers the eastern area will be seriously in danger (Fig. 1). The wind speed is high enough to lift and transport the salt grains far from the lake.

The plots show two important facts. The first one is the direction of prevailing winds in these sites. The prevailing winds in Urmia site are from the west, in Mahabad from the southwest and in the Miandoab site are from the south. The second fact is the sustainable areas of danger that are the eastern parts which are mainly affected by Aeolian winds.

The satellite images which have been proceeding in this paper show the extension of wasteland in the eastern parts of the area that is observed in yellow. By comparing Figures 1 and 6, a relationship can be established between the expansion of wasteland and wind direction. It has been proven that during the history of the lake, the salt grains were carried by winds to the eastern lowlands. But the areas with high elevation are safe and expansion of wasteland in western parts is insignificant. Now, it is possible to distinguish the eastern areas that are at the same altitude as the lake bed, are in danger. This means that some populated cities located in the eastern area of the lake may be in trouble in the future because farming is one of the most important businesses in these cities, and their fields are in danger of salt intrusion after the lake has dried. Blowing salts may cause respiratory illnesses, eye problems, and throat and esophageal cancer.

This paper distinguishes the areas in danger by conducting GIS modeling based on historical data on agricultural expansions, dams' constructions and other important elements, namely the wind direction and the altitude of the eastern area. These parameters showed that the lowlands covering the eastern part of the lake are in danger, and GIS modeling and classified images by ENVI 4.7 and index of NDVI were presented as proof for this statement.

4. Discussions

4.1. Aeolian processes

The wind has an ability to transport, erode, and deposit sediments. Generally, Aeolian (or eolian) processes remind us of a desert landscape of displacing sand dunes (Simonett 1968; Brookfield and Ahlbrandt, 1983; Abrahams and Parsons, 1994). Wind plays a key role in a Geo-morphological process that starts with the transportation of sediments, followed by erosion and its eventual deposition. The expanded dried part of Urmia Lake in the eastern area (Fig. 4) with a high concentration of salt can be eroded by the wind's force.
Wind can carry the salt grains to a place far from the lake by an alien process The Aeolian process normally takes place in arid and semi-arid environments, such as dried Urmia Lake.

Aeolian transportation is just saying that particles are being moved by wind; this phenomenon has been abundantly explained by Jain, 2014.

When Aeolian erosion occurs, the wind erodes the salty surface and lifts up salt grains and transports them far from the lake into cultural fields and pollutes them. By considering elevation in front of the wind direction, the specified area in Figure 2 that is shown in yellow is in danger. These areas are located in low altitudes, thus they are in danger because the wind is not obliged to lift up the salt grains and lift them to a height and also the wind can carry them with the creep and the saltation moves too. But other areas with high altitude are safer than lowlands whereas the wind needs more power to lift the salt grains, taking them to the highlands.
A land/soil with the high concentration of salinity is not suitable for agriculture because water penetration into the soil decreases. The spreading of wasteland in the eastern area shows this scenario (Fig. 4-6).

These salt flats will not support agriculture and inhibit growth of most natural vegetation. The salts particle may blow and may create "salt-storms" of Lake Urmia (Hassanzadeh, E. et al. 2012). It is likely that many of the tens of millions of people will experience the impact of these salt storms (Ryahi, H.; Soltani, N.; Shokravi, S. 1994).

5. Conclusions and recommendation for water resources management

Image analysis shows significant changes in wasteland and water level in Urmia Lake (Fig. 3,4,5, and 7). It means that the lake is running dry. The amount of fresh water entering the lake is only such that it can temporarily bring the salinity to about 300 grams per liter so it cannot dissolve the salt of the bed, and vice versa. The onset of summer begins to precipitate and cause the salt to thicken. If the drying process continues, the salt storms will deteriorate the soil, water and whole environments of the vast area in this part of country.

The most important cause of lake dryness are climate changes, population growth, dam construction and agriculture expansions. Among these causes, dam constructions has more drastic effects on Urmia Lake. The authors suggest any further dam constructions must be ceased and for current dams the basic ecological needs of water for restoring the life in Urmia Lake must be provided and that is 50 present of volume of water in the lake in seasons with high rainfall (winter and spring) and 15 to 25 present of water must be released during the season with low precipitations.

Managing the agricultural and horticultural activities and the ground water wells located in the lake basin is the second and third most necessary action plan that must be done for restoring life to Urmia Lake.

6. Conflict of view

For this paper there is no Conflict of Interest.

References:

Abrahams A. D. And Parsons, A. J. (1994). Geomorphology of desert environments. Edited by Athol D. Abrahams and Anthony J. Parsons. Published by Chapman and Hall, London. ISBN 978-94-015-8256-8.

Babayan A., Hakobyan S., Jenderedjian K., Muradyan S. And Voskanov M. (2003). Lake Sevan, lake basin management initiative experience, and lessons learned brief. Lake basin management initiative regional workshop in Europe. Central Asia and the Americas held at Saint Michaels College in Vermont, USA, 18-21 June. http://www.worldlakes.org/uploads/sevan_01oct2004.pdf

Bayes Ahmed, Raquib Ahmed, Xuan Zhu, 2013, Evaluation of Model Validation Techniques in Land Cover Dynamics, ISPRS International Journal of o-Information.
www.mdpi.com/journal/ijgi/, ISPRS Int. J. Geo-Inf. 2013, 2, 577-597; doi: 10.3390/ijgi2030577

Brookfield M.E., Ahlbrandt T.S. (1983) Eolian sediments and processes. Elsevier, New York in Brooks A. And Agate, E. (Eds) (1997). Sand Dunes: A practical handbook, 3rd edition, British Trust for Conservation Volunteers, Wallingford.

Chander G. and Markham B. (2003). Revised Landsat-5 TM radiometric calibration procedures and post calibration dynamic ranges. Geoscience and Remote Sensing IEEE Transactions, http://ieeexplore.ieee.org/xpl/RecentIssue.jsp?punumber=36 Vol. 41, Issue 11.

Custodio E. (1985). Saline intrusion, hydrology in the service of man. Memories of the 18th Congress of the International Association of Hydrogeologists, Cambridge, pp. 65-90.

Cohen, J. A coefficient of agreement for nominal scales. Educ. Psychol. Meas. 1960, 20, 37–46.

Eimanifar A., Rezvani S. and Carapetian J. (2006): Genetic differentiation of Artemia urmiana from various ecological populations of Urmia Lake assessed by PCR amplified RFLP analysis. Journal of Experimental Marine Biology and Ecology, 333 (2), pp 275-285.
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.193.215&rep=rep1&type=pdf

Hassanzadeh E., Zarghami M., and Hassanzadeh Y. (2012). Determining the main factors in declining the Urmia Lake level by using system dynamics modeling. Journal of Water Resource Manage, Vol. 26, pp. 129-145. Article in Water Resources Management· October 2012 DOI: 10.1007/s11269-011-9909-8.

Jain, S. (2014). Fundamentals of Physical Geology, Springer Geology, DOI: 10.1007/978-81-322-1539-4-13, Springer India.

Kitada, K.; Fukuyama, K. Land-use and land-cover mapping using a gradable classification method. Remote Sens. 2012, 4, 1544–1558.

Long, J.B.; Giri, C. 2011, Mapping the Philippines' mangrove forests using Landsat imagery. Sensors 2011, 11, 2972–2981.

Malian A., Mohamadi A., Valiallahi J. 2017. "Detection and prediction of the trend of Lake Urmia and its surrounding environment over the past half century on the basis of the remote sensing spatial analysis of the location." Journal of Hydro-geomorphology,No 9, 2017 pages: 43-62, in Persian.http://hyd.tabrizu.ac.ir/article_6180_71b3a7e9fba531bb345de4ed7e644b35.pdf

Marjani A. and Jamali M. (2014). The role of exchange flow in the salt water balance of Urmia Lake.http://www.sciencedirect.com/science/article/pii/S0377026513000559 . Original Research Article, Dynamics of Atmospheres and Oceans, Vol. 65, March 2014, pp. 1-16.

Manaffar R, Zare S, N. Agh, Siyabgodsi A, Soltanian S. 2011, Sediment cores from Lake Urmia (Iran) suggest the inhabitation by parthenogenetic Artemia around 5,000 years ago - Hydrobiologia, 671 (1), 65.

Mostofie N, Fataei E, Hezhabrpour Gh, Kheikhah Zarkesh MM. (2014) Assessment centers and distribution centers dust (case study:NorthWest,Iran) , International Journal of Farming and Allied Sciences, 3 (2): 235-243.

National Cartographic Center (NCC), Iran. http://www.ncc.org.ir/

Pontius, R.G., Jr. 2000, Quantification error versus location error in the comparison of categorical maps. Photogramm. Eng. Remote Sensing 2000, 66, 1011–1016.

Pontius, R.G., Jr. 2002, Statistical methods to partition effects of quantity and location during comparison of categorical maps at multiple resolutions. Photogramm. Eng. Remote Sensing 2002, 68, 1041–1049.

QIU Han-xue, LIU Dong-yan, LIU Guan-qun and NING Pi-hai (1997). Saline water intrusion and its influence in the Laizhou Area. Chin. J. Oceanol. Limnol., Vol 15, No. 4, pp. 342-349.

Ryahi, H.; Soltani, N.; Shokravi, S. 1994, Study of Urmia Lake algae flora. Pajouhesh-va-Sazandeghi 1994, 25, 23–25. www.alireza-asem.ir/Asem23.pdf

Sima S. and Tajrishy M. (2013). --Using satellite data to extract volume eare aelevation relationships for Urmia Lake, Iran. Original Research Article. Journal of Great Lakes Research, Vol. 39, Issue 1, March 2013, pp. 90-99. http://www.sciencedirect.com/science/article/pii/S0380133012002493

Simonett D. S. (1968). Wind action. In: Fairbridge R.W. (ed.) Encyclopedia of Geomorphology. Reinhold, New York, pp 1233-1236.

Williams V. J. (2010). The ecological effects of saltwater intrusion on the agriculture industry after Hurricane Katrina. Journal of Sustainable Development, Vol. 3, No. 1, pp 29-37. http://www.ccsenet.org/journal/index.php/jsd/article/viewFile/3821/4458 .