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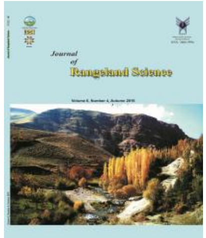

Research and Full Length Article:

Efficiency of Spectral Indices Derived from Landsat-8 Images of Maharloo Lake and Its Surrounding Rangelands

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Abstract. Maharloo Lake is one of the salty lakes located in the southeast of Fars province, Iran. Presence of salt domes has a significant role in its salinity. Magnesium-sodium chloride and sodium sulfate are dominant salts of the lake. Due to the drying up of lake, widespread lands surrounding the area are exposed to secondary salinity. It seems necessary to investigate the changes to find salinity level in order to predict the changes of vegetation and its margin uses. The purpose of the study was to evaluate the spectral indices derived from the images of Landsat8 sensors in detection of salty levels of the Maharloo Lake. In this study, Landsat8 imagery was used to obtain salinity indicators in the salt lake. Fourteen salinity indices have been calculated using the ENVI. The results showed that the indices of BI, SI, SI1, SI2, SI3, VSSI, YSI and SR could detect the area covered by salt crust on the lake and then, isolate and separate it from the rest of reflection spectrum. However, MSI and NDBI indicators were unsuccessful in detection of salt crust. NDVI and COSRI indicators used in plant detection could not detect the salt crust and just identified the typical vegetation. Finally, I2 and NDSI indicators also partially with low accuracy succeeded to detect some salinity areas and had no satisfactory performance.

Keywords: Maharloo Lake, Remote sensing, Salinity indicators, Landsat8, Rangeland

Introduction

Much of the country renewable natural resources may be altered with a regressive trend due to the lack of proper management and optimum utilization (Ebrahimi *et al.,* 2011; Zehtabian *et al.,* 2013). Vegetation cover pattern is an important factor in rangeland management and needs accurate mapping and monitoring (Zaremehrjardiri, 2011). Salinization in arid and semiarid areas is one of the greatest hazards for rangeland. High concentration of soluble salts on the surface and near the soil surface horizons is one of the major problems of global and society economies. Salinity of soil as an effective factor has a significant role in the plant distributions which have made some problems in the agricultural activities (Jafari, 1990; Abarsaji *et al.,* 2012). Additional salt concentration in the soil increases the soil degradation processes and reduces the crop yields and agricultural production (Farifteh *et al.,* 2007). Identifying the early stages of salinity processes and also assessing the development and severity degree of salinity are crucial in sustainable management of soil, especially in semi-arid areas where the climatic conditions suddenly change and population density increases rapidly so that it needs to increase productivity in agriculture and change the land use. On average, 20 percent of the world water lands are affected by salt and this amount in such countries as Iran and Egypt has been reported up to 30%. Extent of the soil affected by salinity in Iran is estimated between 23 to 25 million hectares, which is affected by the primary and secondary salinity to different degrees (Matinfar *et al.,* 1995). Salinity affects other aspects such as degradation, erosion, soil and engineering affairs. Economic losses caused by the salinity of the lands are significant. For example, economic losses caused by the secondary salinity for the surrounding lands of the Colorado River are about 750 m $ a year and for Punjab and North West of Pakistan are 300 and 208 m $ per year to Australia (Ghassemi *et al.*, 1995; Matinfar *et al.*, 1995).

Salinity of the surface is an active process so that this feature affects the extracted data from usual methods with spectral and spatial data of this phenomenon. Surface salinity is an active process; this process affects the identification of salinity soils and the monitoring of salinization process because the spectral, spatial and temporal characteristics influence the salinity phenomenon. Field observations and radiometric measurements show that the main factors affecting the reflection of saline soils are quantity and mineralogy of salts and soil moisture, color and surface roughness (Farifteh *et al.,* 2007). Today, with advances in science, the use of new technologies such as receiving and processing the data via satellites and information processing system play a major role in the management of water resources and soil (Daem Panah *et al.,* 2011). The ability of satellites in providing an overview is a unique tool for fast and timely monitoring of ground resources and identification of the areas affected by salinity (Ding *et al.,* 2011). Remote sensing includes identification, collection and interpretation of data.

Investigation of salt-affected soils with remote sensing techniques due to specific properties of salinity such as accumulation of salts in the soil surface in the form of white shell with high reflectivity and spectral characteristics of salt mineralogy will bring the desired results (Meternich and Zinc, 2009). Identification of saline soils using remotely sensed data greatly depends on the moisture, salinity class, crusts and saline surface spectral reflectance contrast as compared to surface spectral reflectance of other phenomena. Generally, the identification of lands with high and moderate salinity is more successful than the low salinity lands and areas that are in the early stages of salinity (Matinfar *et al.,* 1995). Spectral reflection of the areas mainly depends on the mineralogy of salt that defines the presence or absence of the dominant absorption spectrum in the electromagnetic spectrum (Ding *et al.*, 2011). Mineralogy of salts, which controls the spectral absorption areas within the certain ranges of the electromagnetic spectrum, affects the appearance of representative complications of soil salinity complications such as puffy rusts and land cover pattern. Salinity surface indicators can be extracted directly or indirectly from the satellite images; direct extraction refers to the complications that are clearly visible at the soil surface and indirect one refers to the presence of halophyte vegetation or crops resistant to salinity of soil surface (Meternich and Zinc, 2009).

By studying the spectral properties of salt crusts covered by soils, pure halite cannot lead to the attraction of near visible and thermal infrared bands (Howari *et al.*, 2002). Fig.1 shows the salt ranges in the visible area, near infrared and middle ones measured by Spectro radiometer:

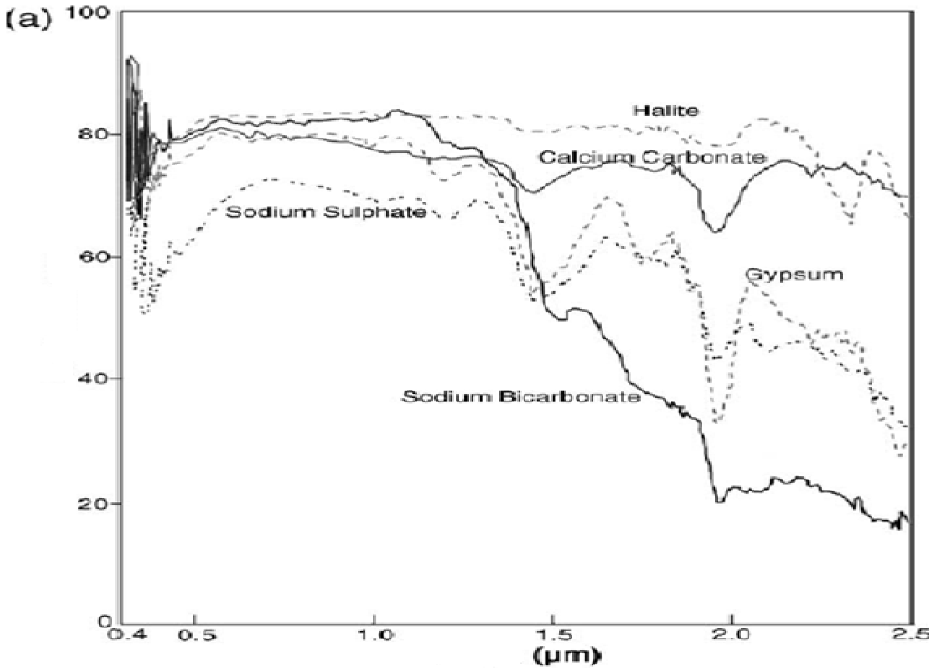

Fig. 1. Plaster range (CaSO4.2H2O), halite (NaCl), calcium carbonate (CaCO3), sodium bicarbonate (NaHCO3) and sodium sulphate (Na2SO4) in the visible, near infrared and middle area (0/4-2/5 nm) are measured by (GER 3700) Spectroradiometer (Howari *et al.*, 2002).

The most common used technique to identify salinity is the calculation of different indicators from infrared and visible bands. Khan and Abbas (2007) proposed three spectral indicators to determine the salinity using the LISS-II sensor that is installed on the satellite IRS-1B. These indicators are brightness index (BI), salinity index (SI) and Normalized Differential Salinity Index (NDSI). The researchers found that among these three indicators, NDSI is more successful in the identification and extraction of different classes of salinity (Dehni and Lounis, 2012). It was found in Savojbolagh, Karj, Iran that the SI and BI indicators are capable to detect saline lands (Meternich and Zinc, 2009). VSSI and NDSI Indicators in the Oran area of Algeria have positive correlation coefficients in three periods (1987, 2002, 2009) and ETM^{+} sensor is used to understand the relationship between the salinity indicators and plant for correct interpretation of soils affected by salinity (Dehni and Lounis, 2012). The purpose of this study was to evaluate the usability of salinity indicators in severe salinities like salty crust formed in Maharloo Salt Lake, Fars province, Iran that should have a safe and fast way to find out the status of salt in the areas due to the drying of the Lakes and inland wetlands.

Materials and Methods

Study area

Maharloo Lake is located in 48º 52´ E and 27º 29´ N in Fars province, Iran about 28 km south-east of Shiraz city (Fig. 2). The average elevation is 1460 m from sea and its maximum depth is 3 m. Severe water erosions in the highlands are quite evident due to the regional climate, geological and lithological structure of heights overlooking the Maharloo Lake and torrential case heavy rainfalls. Some studies conducted on the lake showed the widespread precipitation of materials from severe erosion of the surrounding mountains' aquifers which may reduce the wetland depth, especially in the West side (http://www.earthwatchers.org). Vastness of Maharloo Wetland is 20800 hectares with a length of 35 km so that the evaporation rate is high and part of its base is covered with a layer of salt and only in its northern and central parts, water with very little depth (max. 50 cm) and high salinity exists. Its vastness is different in various seasons and is subjected to atmospheric precipitation. Apart from high evaporation, plaster deposits of Sazand Sachoon and two salt domes located in the east of the lake have significant impacts on its immeasurable salinity.

Fig. 2. Locattion of study area in Iran

Topography

Maharloo Lake is formed in a syncline-like subsidence with a northwest-southeast trend and in a sense is one of the large-scale Playa Lakes in the area that the young and seismic fault of Sarvestan passes from it (http://www.earthwatchers.org). Salinity compounds of the lake water are mainly sodium chloride, magnesium chloride and sodium sulfate and salt of the lake is used for petrochemical industries. High potassium and magnesium in the brines of the Maharloo Lake make it possible to economically use magnesium salt as a main product and potassium as a byproduct.

Remote sensing of satellite images

Image of Landsat8 OLI/TIRS sensors was taken on the sixth of May 2014[1] and used in the ENVI 5 after preprocessing (Table 1). We used the Dark Subtract method in the software to correct the systematic error of the sensor.

[1] Download from, earthexplorer.usgs.gov

Table 1. Technical details of Landsat8 sensors (OLI-TIRS)

Band Number	Band Type	Wavelength (μm)	Spatial Resolution (m)
1	Ultra Blue	0.433-0.543	30
2	Blue	0.450-0.515	30
3	Green	0.525-0.600	30
4	Red	0.630-0.680	30
5	NIR	0.845-0.885	30
6	SWIR1	1.560-1.660	30
7	SWIR2	2.100-2.300	30
8	Panchromatic	0.500-0.680	15
9	Cirrus	1.360-1.390	30
10	TIRS1	10.6-11.2	100
11	TIRS2	11.5-12.5	100

Calculation of indicators

ENVI was used to process the images and calculate the indicators. After the calculation of indicators, output images were shown and then evaluated. Indices and their equations are presented in Table 2.

Sampling points

In order to identify spectral reflectance of saline crusts on lake and its surrounded rangelands, for each band of Landsat8 sensors, 50 points from the whole surface of the lake and surrounding rangelands were chosen (Fig. 3).

Table 2. Salinity indices

Index	Equation	Definitions	References
NDBI	(TIR[2]-NIR[3])/(TIR+NIR)	Normalized Different Build up area Index	Dehni and Lounis, 2012
VSSI	2*G[4]-5*(R[5]+NIR)	Vegetation Soil Salinity Index	Dehni and Lounis, 2012
BI	SQRT[6]($(R)^2+(NIR)^2$)	Brightness Index	Dehni and Lounis, 2012
SI	SQRT(R*NIR)	Salinity Index	Dehni and Lounis, 2012
SR	(R-NIR)/(G+NIR)	Salinity Ratio	Dehni and Lounis, 2012
NDVI	(NIR-R)/(NIR+R)	Normalized Different Vegetation Index	Dehni and Lounis, 2012
NDSI	(R-NIR)/(R+NIR)	Normalized Different Salinity Index	Dashtakian *et al.*, 2008
YSI	(R-B[7])/(R+B)	Yield Salinity Index	Dashtakian *et al.*, 2008
SI1	SQRT(G*R)	Salinity 1	Tajgardan *et al.*, 2009
SI2	SQRT($(G)^2+(R)^2+(NIR)^2$)	Salinity 2	Tajgardan *et al.*, 2009
SI3	SQRT($(G)^2+(R)^2$)	Salinity 3	Tajgardan *et al.*, 2009
MSI	SWIR1[8]/NIR	Modified Salinity Index	Tajgardan *et al.*, 2009
I2	(NIR-SWIR1)/(NIR+SWIR1)	Index 2	Khaier, 2003
COSRI	(B+G)/(R+NIR)*NDVI	Combined Spectral Response Index	Fernandez-Buces *et al.*, 2005

[2] Thermal Infrared
[3] Near Infrared
[4] Green
[5] Red
[6] Square Root
[7] Blue
[8] Shortwave Infrared

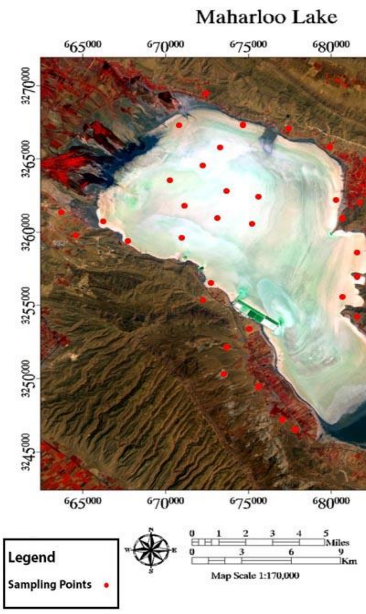

Fig. 3. Sampling points map

These sampling points of lake were categorized in two groups: the mean brightness degree of total lake (MBDTL) and the mean brightness degree of the lake center (MBDLC). At first, the mean of spectral reflectance of selected pixels (sampling points) in each band for central part of the lake and then, the mean of spectral reflectance of the whole lake were calculated.

Results and Discussion

One of the natural hazards that have always been important to mankind is the salinity, salt-affected soils and degradation of vegetation. In recent years with the development of science and technology, remote sensing techniques have been used to determine the rangeland and salt-affected areas. Images of Landsat8 satellite are useful to determine the scope and identify salty and sodium soils (Dehni and Lounis, 2012). Using false color composite images, vegetation indices and salinity indicators are procedures used in remote sensing of areas affected by salinity. In this study, the obtained images from the indices were interpreted visually to determine the areas affected by salinity (Fig. 4).

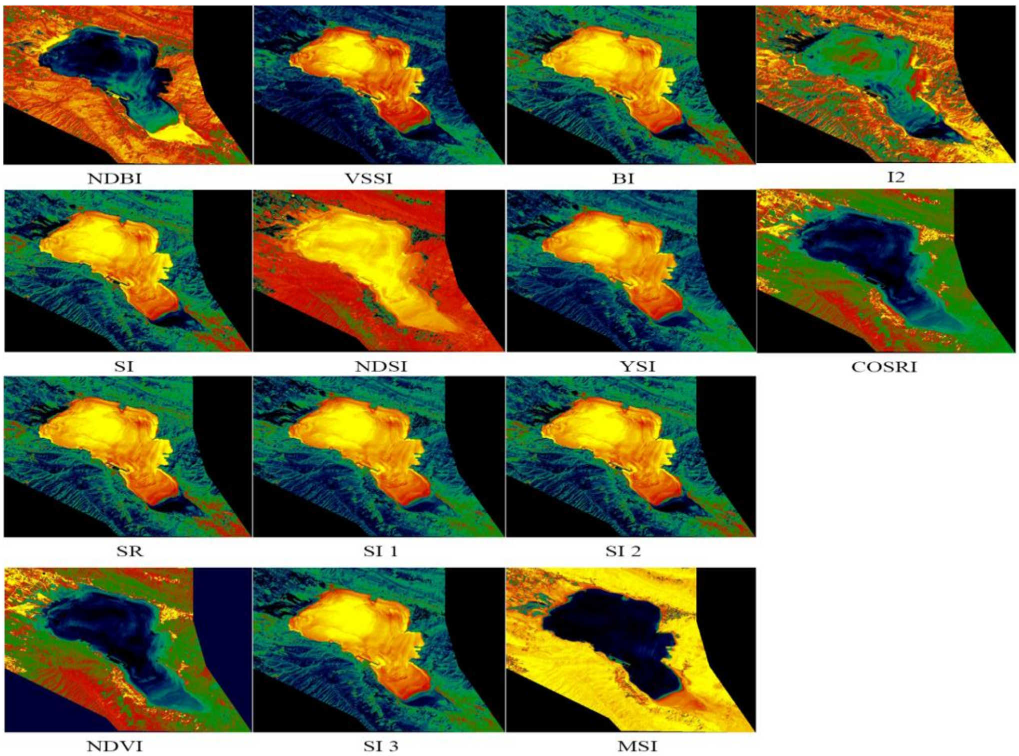

Fig. 4. The images obtained from indices on the satellite image. The yellow areas in indicators of BI, SI, SI1, SI2, SI3, VSSI, YSI and SR are salt-affected area

Soils with electrical conductivity (EC) more than 2 ds/m are considered saline. The plants that can be naturally established in saline soils and drought soils are called halophytes. Salinity, aridity and grazing stress reduce nutrient uptake by roots and eventually cause plant death. Thus, soil salinity, soil aridity and grazing stress can reduce rangeland production potential (Sepehry *et al.*, 2012). Comparing the results showed that among the calculated indices, SI, BI and SR indicators were identified well with high accuracy of 85%, 79% and 75%, respectively. The saline areas of the lake such as salt crust were formed on the surface of the lake and salt-affected rangelands in the southeastern side of the lake. Success of the indices can be linked to the amount of high spectral reflection in the R and NIR bands. As shown in Fig.5, the amount of spectral reflection of the salt crust formed on the surface of the lake is high in these two spectrums; on the other hand, they are used in the index formula of all three mentioned indices (Fig. 5). SI1, SI2 and SI3 indicators have high abilities to detect the salt crust formed on the surface of the lake. In the meantime, the results of SI2 index have most similarity to the SI, BI, and SR indices and detected the salinity soils better than the SI1 and SI2 indices in the southeastern side of the lake. In these three indices, G band has been used in addition to R and NIR bands. This slight difference in the results can be the result of G band use in the formula of the indices and calculation kind of image.

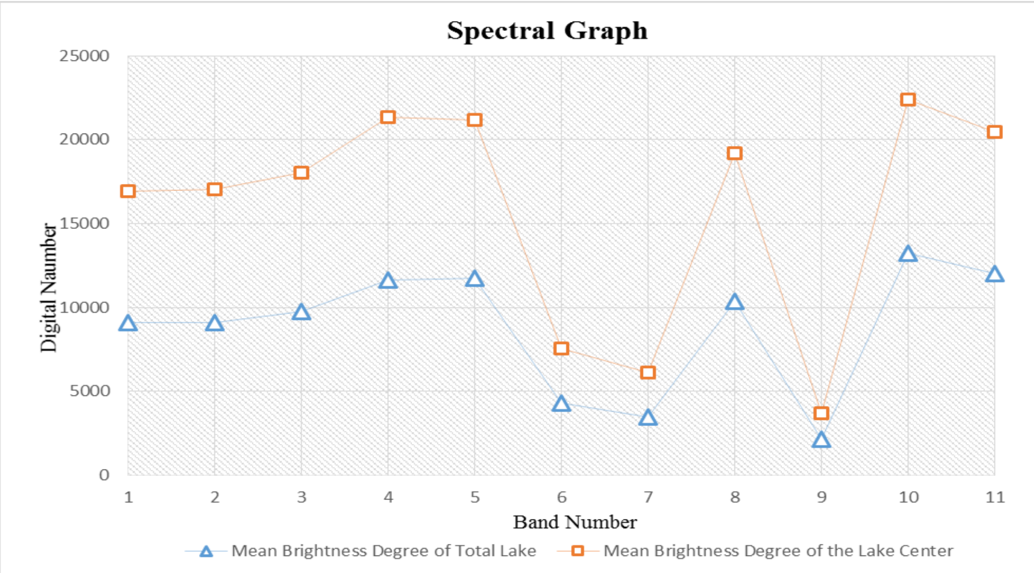

Fig. 5. Spectral graph of the Maharloo Lake's surfaces

VSSI and YSI indicators act well in the detection of a salt crust formed on the lakebed. Like indicators of SI, BI, SR, SI1, SI2 and SI3, they separated the salt crust of the lake center and the salts of the southern part of the lake well that had different reflections due to being mixed with water. But they weren't successful in the determination of salinity soils formed in the southeastern side of the lake. After the evaluation of successful indicators, other indices that gave different results included NDBI, I2, COSRI, NDVI and MSI, respectively. NDBI index generally failed in the detection of salt crust at the lake center as well as other salt parts of the lake. Since NIR and TIR bands are used in NDBI formula and have the most reflection based on Fig 5, the failure of the index probably was related to the kind of lake salts because the index is a made indicator for the Oran region of Algeria (Dehni and Lounis, 2012) and cannot be useable for the Maharloo Lake. Index I2 detected very low salinity irregularly in the central part of the lake but it has been unsuccessful in total. SWIR1 band was used in the formula of the index. Fig.5 shows that the brightness level of the band (SWIR1) is much less than the other bands. MSI index has been unsuccessful in the detection of salinity crust of the lake.

Two indicators of NDVI and COSRI could not detect the saline areas and just detected the vegetation around the lake: the first one is used in the detection of the vegetation and the second is a combination of NDVI and B, G, R and NIR bands (is used for bare soil and vegetation).

Vegetation management is the most important factor in saline and arid land management (Sepehry *et al.,* 2012). Salinity indicators derived from remote sensing of satellite imagery are the fastest and most accurate methods in the detection of salinity regions which corresponded with the results of Yong-Ling *et al.* (2010). These indicators act based on the spectral reflection values and brightness levels of the image pixels. Some of these indicators provided results that can be used in monitoring the salt areas but others are created for certain points and act due to the physiographic structure of the region, humidity, salt kind, roughness and smoothness of the surface and color of the background soil and are not usable in other parts. Some of the most famous salt indicators were examined in the study to detect the salt crust of the Maharloo Lake, and among them, the indicators of SI, BI, SR, SI1, SI2, SI3, VSSI and YSI have acted reasonably and successfully which corresponded with the results reported by Dehni and Lounis (2012) on the application of salinity indices to map Algeria region. By the identification of saline area around the lake, the ability to control and prevent the salinity progression will be increased. When the lake begins to dry out, saline crust on its surface will appear. These salts may be transferred by wind and then, cause secondary salinity. Salinity weather primary or secondary will affect the rangelands and agricultural land surrounding the lake. Finally, protection, restoration and reconstruction of natural areas will be possible when their natural and biological capacity is evaluated with regard to restrictions (Chamapira and Taghavi Goudarzi, 2011).

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بررسی شاخص‌های طیفی منتج از ماهواره لندست ۸ در بارز سازی نواحی شور دریاچه مهارلو و مراتع اطراف آن

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چکیده. دریاچه مهارلو یکی از دریاچه‌های شور داخلی واقع در جنوب شرقی استان فارس می‌باشد. وجود گنبدهای نمکی در شوری آن نقش به سزایی دارد. نمک‌های غالب این دریاچه کلرید سدیم-منیزیم و سولفات سدیم می‌باشد. با توجه به خشک شدن این دریاچه اراضی اطراف آن به وسعت خیلی زیاد در معرض شوری ثانویه قرار می‌گیرند. هدف از این پژوهش ارزیابی شاخص‌های طیفی منتج شده از سنجنده‌های ماهواره لندست ۸ در آشکارسازی سطوح نمکی دریاچه مهارلو می‌باشد. در این تحقیق از تصویر ماهواره لندست ۸ برای به دست آوردن شاخص‌های شوری در این دریاچه نمکی استفاده شد. ۱۴ شاخص شوری با استفاده از نرم افزار ENVI 5 مورد محاسبه قرار گرفتند. نتایج نشان داد که شاخص‌های BI، SI، SI1، SI2، SI3، VSSI، YSI و SR توانستند به خوبی نواحی با پوسته نمکی تشکیل شده بر روی دریاچه را شناسایی و آن را از سایر طیف‌های بازتابی جدا و تفکیک کنند. اما شاخص‌های MSI و NDBI در بارزسازی پوسته نمکی تشکیل شده ناموفق عمل کردند. شاخص‌های NDVI و COSRI نیز با توجه به اینکه برای شناسایی گیاهان بکار می‌روند، نتوانستند پوسته شوری را شناسایی کنند و فقط پوشش گیاهی را بارز کردند. سرانجام شاخص‌های I2 و NDSI نیز به صورت نسبی و با دقت کم موفق شدند برخی نواحی شوری را بارز کنند و عملکرد رضایت بخشی نداشتند.

کلمات کلیدی: دریاچه مهارلو، سنجش از دور، شاخص های شوری، لندست ۸، مرتع