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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Analysis of decadal land cover changes and salinization in Urmia Lake Basin using remote sensing techniques" *by* Yusuf Alizade Govarchin Ghale et al.

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Dear Prof. Rosa Lasaponara,

Editor

Journal of Natural Hazards and Earth System Sciences

We would like to thank you and to the second reviewer for the valuable comments that improved the quality of our paper. The manuscript has been thoroughly and carefully revised according to the reviewers' comments. Below are the responses given to the comments raised by the reviewer. Sincerely,

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Reviewer #2:

Comment 1- The proposed methodology is exclusively based on satellite images. An extensive climatic analysis is missing. I think this is a critical point, since, as correctly emphasized by Authors, starting from 2014 something is changing, possibly due to precipitation increase.

Author's Respond:

As the referee has pointed out, this study is exclusively based on remote sensing technology and image processing techniques. Earlier, we have done a detailed study on climate's role and main factors behind the drying up of Urmia Lake in our published paper "Investigation Anthropogenic Impacts and Climate Factors on Drying up of Urmia Lake Using Water Budget and Drought Analysis. Alizade Govarchin Ghale, Y., Altunkaynak, A. & Unal, A. Water Resour Manage (2018) 32: 325. https://doi.org/10.1007/s11269-017-1812-5)". In this study, we have found that anthropogenic factors play a crucial role in water level fluctuations of Urmia Lake and their effect on the lake are more significant than the climatic factors. We have included the results of our published paper in the manuscript (page 2, lines 15-20) to summarize the climatic analysis. Moreover, we have explained the reasons behind the increasing water surface area of Urmia Lake on page 14, lines 23-29. Unfortunately, the data of Urmia Lake Basin meteorological stations are available up until 2014, and there is no public access to the data after 2014.

Edits to the manuscript: Page 2, lines 17-21:

Alizade Govarchin Ghale et al., (2018) have done a detailed study on climatic conditions and main factors behind the drying up of Urmia Lake. They have concluded that anthropogenic factors play a crucial role in the water level fluctuations of Urmia Lake and their impact on the lake is more significant than climatic factors. According to their

study results, impact of precipitation and evaporation factors on drying up of Urmia Lake in recent years, 17% and 3%, respectively, and anthropogenic factors account for about 80% of the shrinking Urmia Lake.

Edits to the manuscript: Page 18, Lines 10-15:

The water surface area of Urmia Lake has increased after 2014. The scientific reports of meteorological office of Iran and Urmia Lake Restoration Program indicate that precipitation has increased between 2014 and 2016. In addition, the government claims that they have released more water from dams into the lake to prevent the complete drying of Urmia Lake, so it is possible that both climate factors and anthropogenic factors have played a positive role in restoring of Urmia Lake from 2014 to 2016.

Comment 2- It is not clear the relation between increase of urban population and lake level decrease. It should be investigated how water distribution systems and water pumping increased, or if new dams were built.

Author's Respond:

We have explained the human impact on Urmia Lake in our published paper in Investigation Anthropogenic Impacts and Climate Factors on Drying up of Urmia Lake Using Water Budget and Drought Analysis. Alizade Govarchin Ghale, Y., Altunkaynak, A. & Unal, A. Water Resour Manage (2018) 32: 325. https://doi.org/10.1007/s11269-017-1812-5).

The detailed information and statistics about anthropogenic impacts on Urmia Lake were analyzed in part "3.3 Human impacts on Urmia Lake" of our published paper. We have explained how established dams and wells have affected water distribution system in Urmia Lake Basin and how mismanagement of water resources in the basin has led to gradual drying of Urmia Lake in recent years. The results of this paper estimated a strong dependency (r=0.87) between population and the area of irrigated lands. In the text, we have made the following edits.

Edits to the manuscript: Page 5, lines 4-13:

The northwest part of Iran is one of the agricultural development centers of Iran, and a variety of products, such as apple, wheat, sugar beet, tomato, potato, and grapes are grown in this region. Dams and groundwater resources provide the required water for developing irrigated lands in the basin. There are in total 103 dams in the West Azerbaijan and East Azerbaijan provinces (Iran Water Resource Management Company 2016). Of these dams, 56 are located in Urmia Lake Basin and 42 of them were built between 1990 and 2014. The area of agricultural lands that have been irrigated by dams has been doubled in the last 15 years (Alizade Govarchin Ghale et al., 2018). Ground water resources such as deep wells and semi deep wells are the other sources of irrigation in the study area. The annual discharge water from ground water resources has increased during recent years. The withdrawal water from groundwater resources was about 2156 mcm in 2012 while it was about 702 mcm in 1972. Therefore, dams and wells prevent water from entering the lake and they have a direct effect on the gradual drying of Lake Urmia.

Comment 3- It is not clear how the agriculture affected the problem of lake depauperation and soil desertification: did irrigation practices changed? Did the crops changed? Apparently in the latest years agriculture decreased, is this related to a low fertility of soils, or to low availability of water?

Author's Respond:

There is not a consistent and extensive database of crop types for the study area, but only one report on this subject and it is not sufficient. In order to monitor the crops grown in the region an extensive field campaign is required. The only available data is related to the scientific reports of the Ministry of Agriculture-Jahad from 2003 to 2013 and this data do not give us any information about crops grown before 2000. The water level of Urmia Lake has decreased dramatically after 1995 and we need to have a complete database about crops before this time. Unfortunately, there is no

public access to this database. According to our results, the area of irrigated lands has decreased during recent years and this could be due to low fertility of soil or low availability of water or even this can be due to water policy changes in the basin in order to provide more water for Urmia Lake. The question asked by the reviewer is beyond the scope of this study. We don't have enough scientific and technical information and updated data from dams, wells and other water resources to judge about the reasons behind the decreasing area of agricultural lands in the study area. This is a question that we have raised in the final section of our paper, in page 18, lines 4-5.

Comment 4- Almost nothing is mentioned about the hydrogeological and geological features of the catchments, I think these important features, which may help the reader in under- standing the investigated problems.

Author's Respond:

We have explained the hydrogeological and geological features of the basin in page 3, lines 2-6.

Edits to the manuscript: page 2, lines 32-39 and page 3, lines 1-7:

Urmia Lake has a surface area ranging between 5000 and 6000 km2 and is located in the northwest of Iran (N 37.5°, E 45.5°) between West Azerbaijan and East Azerbaijan provinces with a catchment area of 51876 km^2. The size of this catchment area is approximately 3% of entire area of Iran. The catchment contains 21 permanent and 39 episodic rivers (Ghaheri and Baghal-Vayjooee, 1999). It is the largest inland lake of Iran and the second largest hypersaline lake in the world (Eimanifar and Mohebbi, 2007; Zarghami, 2011; Hasanzadeh et al., 2012). Saline lakes are susceptible to environmental changes because their properties vary with the changes occur in their hydrologic budgets (Romero and Melack, 1996). The geology of the area ranges from pre-cambrian to Quaternary (Alipour, 2006). By many aspects of chemistry, sediments, and morphology, Urmia Lake is similar to Great Salt Lake in State of Utah in USA. The lake is divided into two parts: northern and southern parts. These parts are separated

by a causeway that has a 1500 m long bridge, which allows little water exchange between two parts (Eimanifar and Mohebbi, 2007; Rezvantalab et al., 2011; Sima and Tajrish, 2013). Its continental climate is affected by the mountains around Urmia Lake and air temperature usually ranges between 0 ° C and -20 ° C in winter and up to 40 ° C in summer. Urmia Lake Basin has an annual average precipitation between 200 mm - 300 mm. (Eimanifar and Mohebbi, 2007). The measured maximum and minimum water surface elevation of Urmia Lake was about 1278.386 m and 1270.168 m in 1995-June and 2014-September, respectively (Iran water resource management company, 2016).

Comment 5- The entire manuscript should be proofread, there are a lot of typos and English is sometimes poor.

Author's Respond:

English of the paper has been improved. Repetitive parts are removed, and general flow of the manuscript has been improved.

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2017-212/nhess-2017-212-AC3-supplement.pdf

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Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-212, 2017.

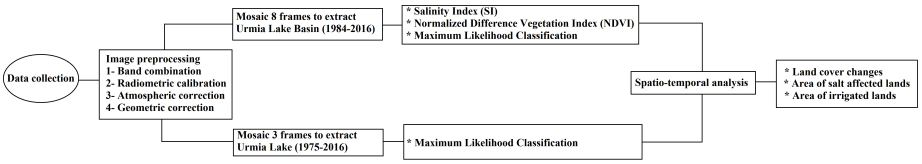
Data collection
Image preprocessing
1- Band combination
2- Radiometric calibration
3- Atmospheric correction
4- Geometric correction
Mosaic 8 frames to extract
Urmia Lake Basin (1984-2016)
* Salinity Index (SI)
* Normalized Difference Vegetation Index (NDVI)
* Maximum Likelihood Classification
Mosaic 3 frames to extract
Urmia Lake (1975-2016)
* Maximum Likelihood Classification
Spatio-temporal analysis
* Land cover changes
* Area of salt affected lands
* Area of irrigated lands

Fig. 1.

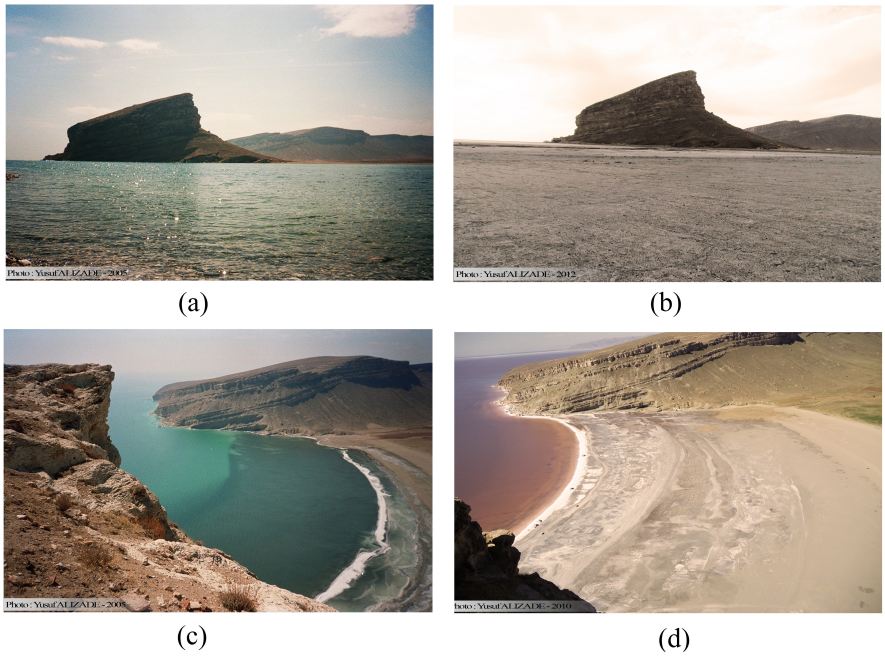
(a)
(b)
(c)
(d)

Fig. 2.

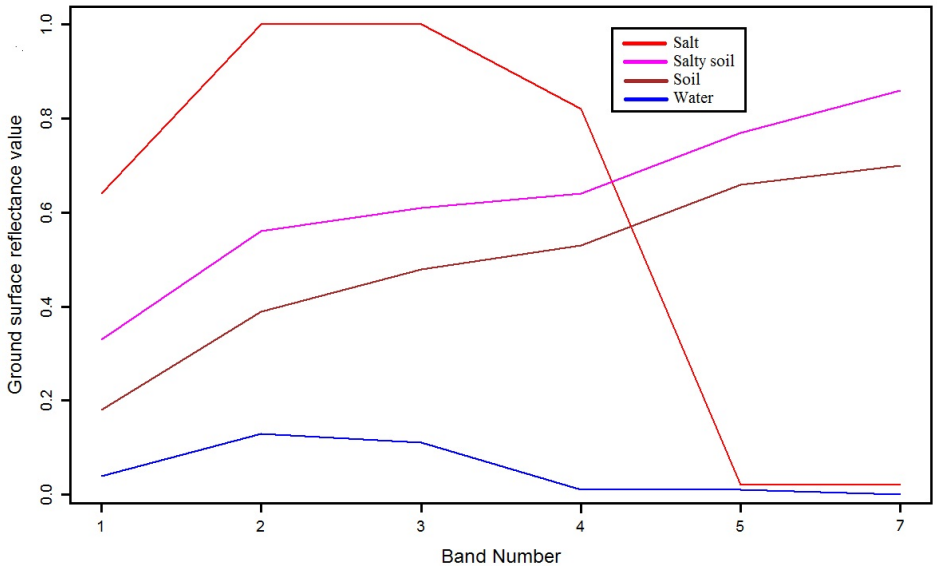
Salt
Salty soil
Soil
Water
Ground surface reflectance value
Band Number
0.0
0.2
0.4
0.6
0.8
1.0
1
2
3
4
5
7

Fig. 3.

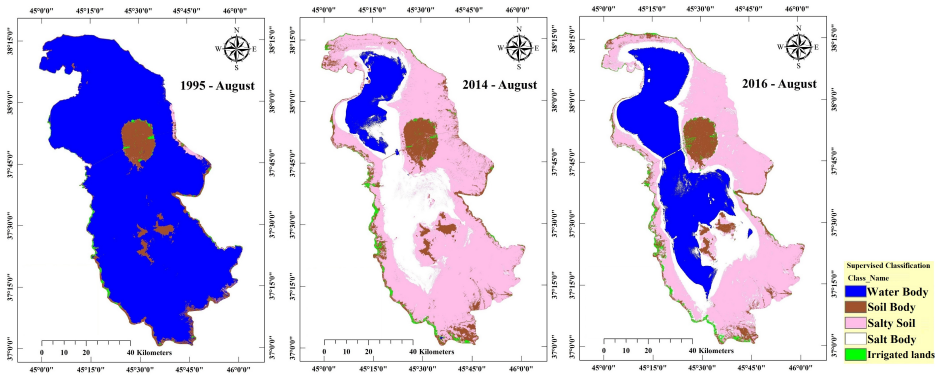
1995 - August
2014 - August
2016 - August
0 10 20 40 Kilometers
Supervised Classification
Class_Name
Water Body
Soil Body
Salty Soil
Salt Body
Irrigated lands

Fig. 4.

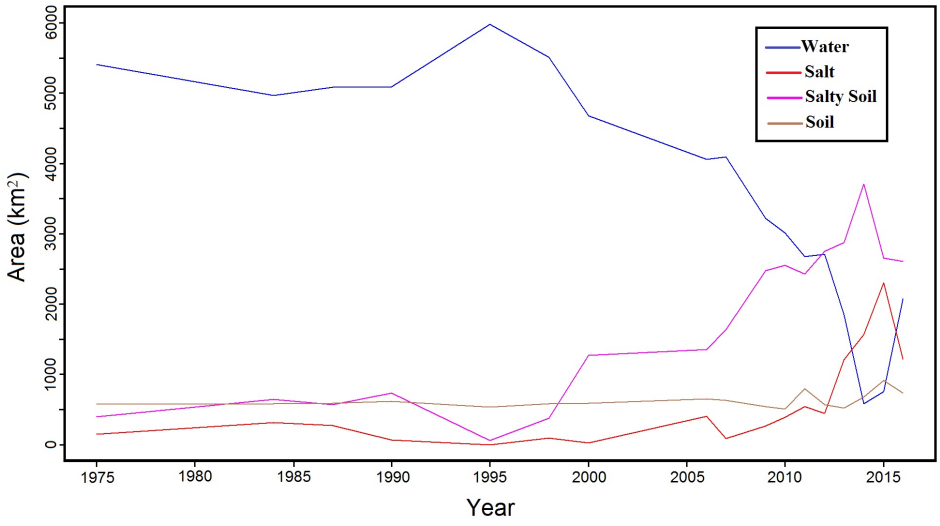
Water
Salt
Salty Soil
Soil
Area (km²)
Year
0
1000
2000
3000
4000
5000
6000
1975
1980
1985
1990
1995
2000
2005
2010
2015

Fig. 5.

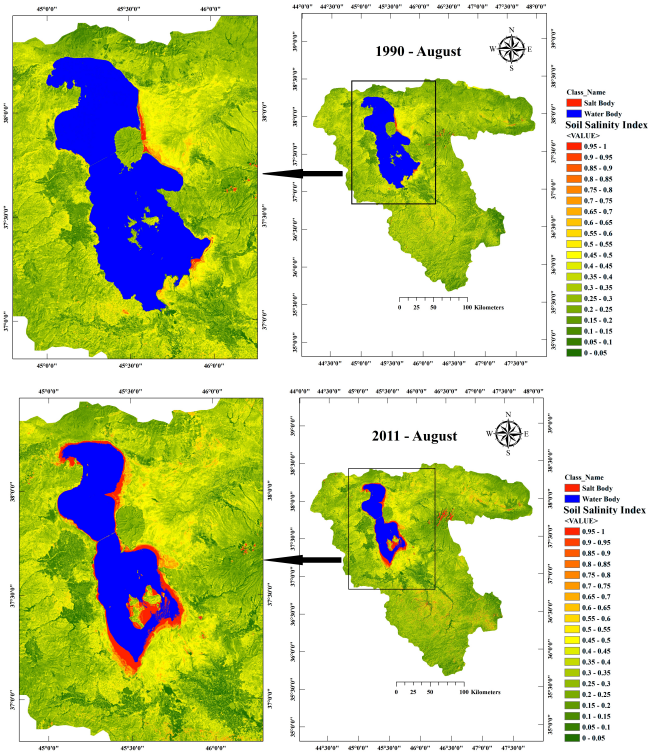
1990 - August
2011 - August
Class_Name
Salt Body
Water Body
Soil Salinity Index
<VALUE>
0.95 - 1
0.9 - 0.95
0.85 - 0.9
0.8 - 0.85
0.75 - 0.8
0.7 - 0.75
0.65 - 0.7
0.6 - 0.65
0.55 - 0.6
0.5 - 0.55
0.45 - 0.5
0.4 - 0.45
0.35 - 0.4
0.3 - 0.35
0.25 - 0.3
0.2 - 0.25
0.15 - 0.2
0.1 - 0.15
0.05 - 0.1
0 - 0.05
0 25 50 100 Kilometers

Fig. 6.

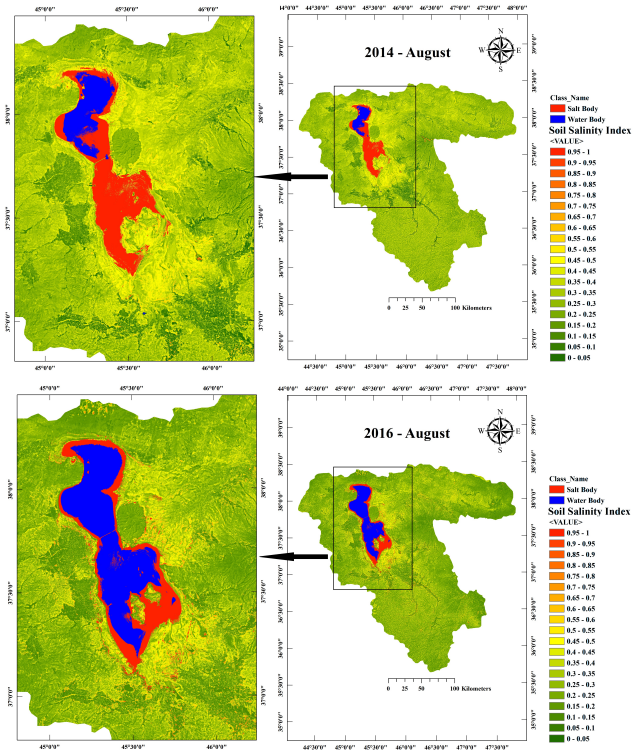
2014 - August
2016 - August
Class_Name
Salt Body
Water Body
Soil Salinity Index
<VALUE>
0.95 - 1
0.9 - 0.95
0.85 - 0.9
0.8 - 0.85
0.75 - 0.8
0.7 - 0.75
0.65 - 0.7
0.6 - 0.65
0.55 - 0.6
0.5 - 0.55
0.45 - 0.5
0.4 - 0.45
0.35 - 0.4
0.3 - 0.35
0.25 - 0.3
0.2 - 0.25
0.15 - 0.2
0.1 - 0.15
0.05 - 0.1
0 - 0.05
0 25 50 100 Kilometers

Fig. 7.

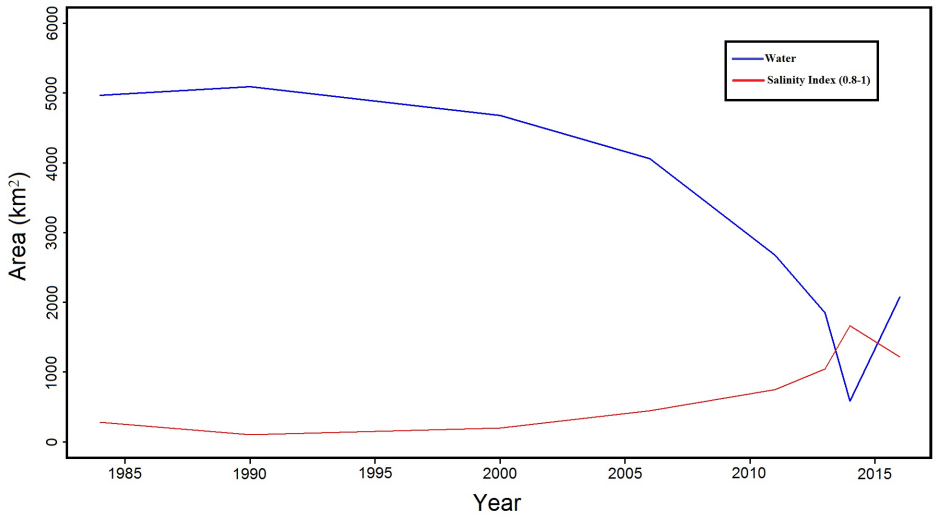
Water
Salinity Index (0.8-1)
Area (km²)
Year
0
1000
2000
3000
4000
5000
6000
1985
1990
1995
2000
2005
2010
2015

Fig. 8.

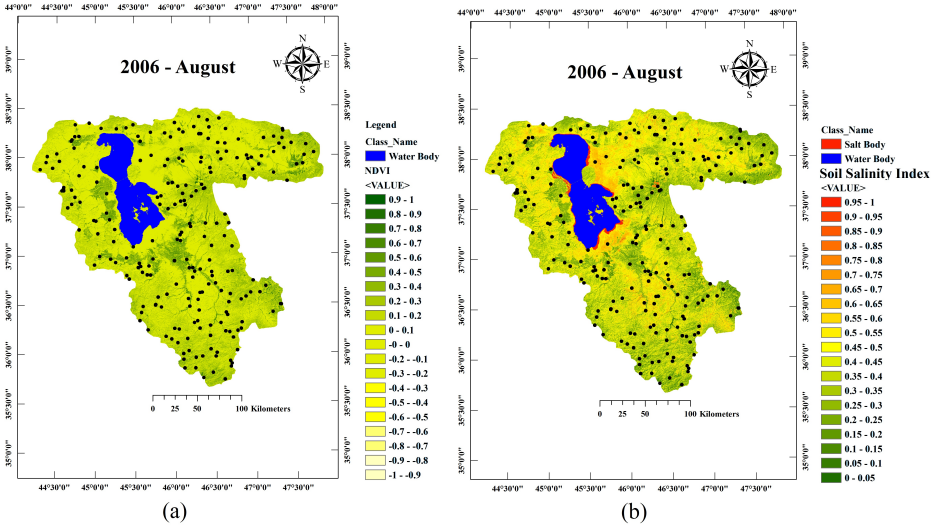
2006 - August
Legend
Class_Name
Water Body
NDVI
<VALUE>
0.9 - 1
0.8 - 0.9
0.7 - 0.8
0.6 - 0.7
0.5 - 0.6
0.4 - 0.5
0.3 - 0.4
0.2 - 0.3
0.1 - 0.2
0 - 0.1
-0 - 0
-0.2 - -0.1
-0.3 - -0.2
-0.4 - -0.3
-0.5 - -0.4
-0.6 - -0.5
-0.7 - -0.6
-0.8 - -0.7
-0.9 - -0.8
-1 - -0.9
0 25 50 100 Kilometers
(a)
2006 - August
Class_Name
Salt Body
Water Body
Soil Salinity Index
<VALUE>
0.95 - 1
0.9 - 0.95
0.85 - 0.9
0.8 - 0.85
0.75 - 0.8
0.7 - 0.75
0.65 - 0.7
0.6 - 0.65
0.55 - 0.6
0.5 - 0.55
0.45 - 0.5
0.4 - 0.45
0.35 - 0.4
0.3 - 0.35
0.25 - 0.3
0.2 - 0.25
0.15 - 0.2
0.1 - 0.15
0.05 - 0.1
0 - 0.05
0 25 50 100 Kilometers
(b)

Fig. 9.

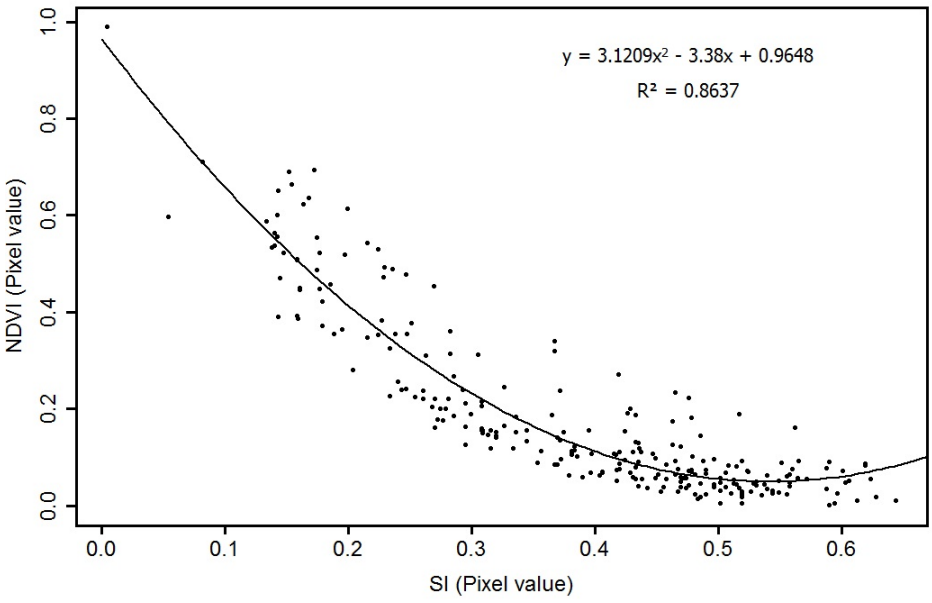
y = 3.1209x² - 3.38x + 0.9648
R² = 0.8637
NDVI (Pixel value)
SI (Pixel value)
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6

Fig. 10.

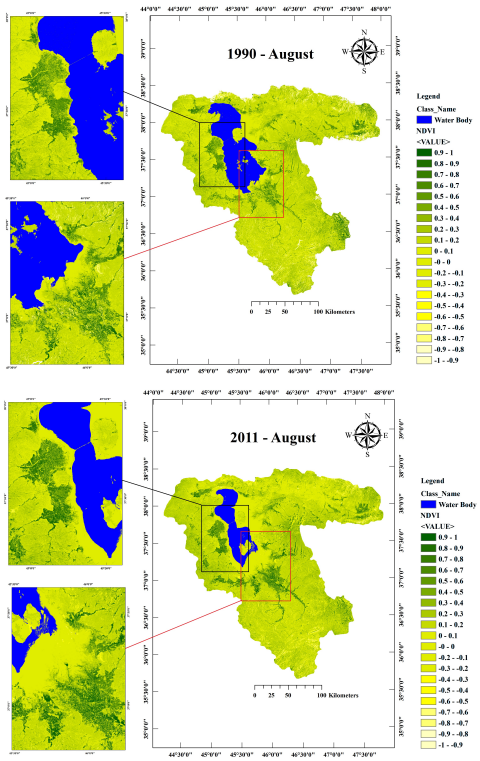
1990 - August
2011 - August
Legend
Class_Name
Water Body
NDVI
<VALUE>
0.9 - 1
0.8 - 0.9
0.7 - 0.8
0.6 - 0.7
0.5 - 0.6
0.4 - 0.5
0.3 - 0.4
0.2 - 0.3
0.1 - 0.2
0 - 0.1
-0 - 0
-0.2 - -0.1
-0.3 - -0.2
-0.4 - -0.3
-0.5 - -0.4
-0.6 - -0.5
-0.7 - -0.6
-0.8 - -0.7
-0.9 - -0.8
-1 - -0.9
0 25 50 100 Kilometers

Fig. 11.

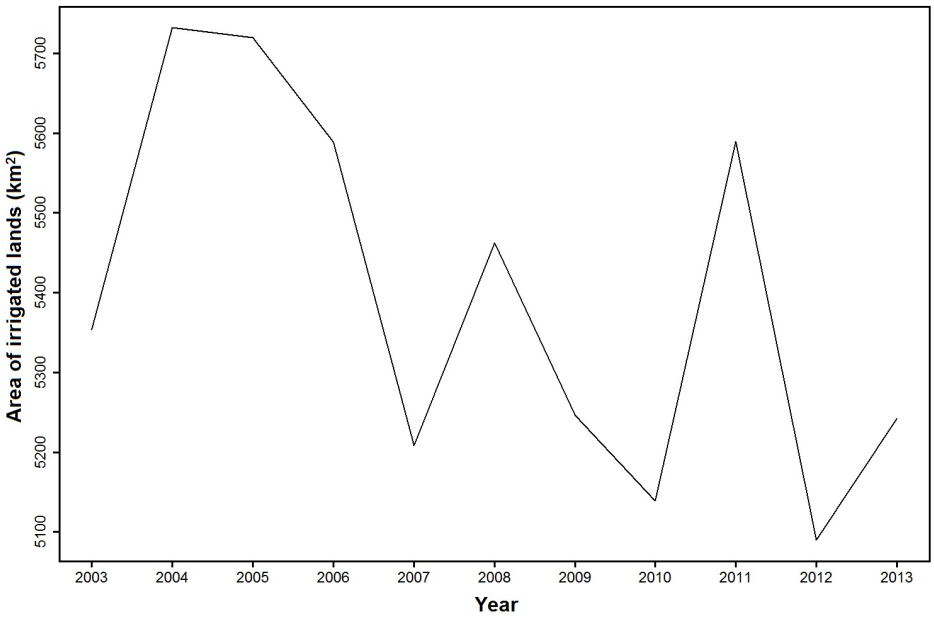
Area of irrigated lands (km²)
5100
5200
5300
5400
5500
5600
5700
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year

Fig. 12.