

Monitoring of organic matter and soil salinity by using IRS - LissIII satellite data in the Harat plain, of Yazd province

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Abstract

Current study monitored Electrical Conductivity (EC) as soil salinity index and Organic Matter (OM) in the area of Harat in Yazd, Iran, through remote sensing technology with high spatial and spectral resolution. The images were selected from IRS, LISS III satellites between the years 2008 and 2012. After preprocessing and analyzing the images, the relationship between parameters of (EC) and (OM) spectral reflections were determined, and both two-satellite images were classified using maximum likelihood method. Results showed that during the period (2008-2012) organic matter content of all farmlands increased and the area of saline land decreased. This trend showed that agriculture activities help reduction of desertification. Accuracy classification and coefficient kappa obtained for salinity map in 2008 were equal to 82% and 0.73, and in 2012, were equal to 84% and 0.70 respectively. Accuracy of classification and coefficient kappa obtained for Organic matter map in 2008 were equal to 85.5% and 0.76 and in 2012, were equal to 84% and 0.74 respectively. This research indicates that remote sensing data, especially IRS-LissIII images, have high efficiency for detection of soil salinity and organic matter changes and natural resources management.

Keywords: Agricultural activity; Harat; IRS-LissIII satellites; organic matter; soil salinity

1. Introduction

Soil salinity that occurs in most arid and semi-arid areas is an important factor in soil degradation. In Iran, soil salinity has been reported to be about 30% including primary and secondary salinity (Hakimzadeh, 2014). However, salinity is one of the problems in the arid and semiarid areas and reduces the quality of the land (Fernandez *et al.*, 2006; Jian-li *et al.*, 2011). Soil organic matter plays an important role in the formation of granular soil structures that are strong and stable structures with high porosity and comfortable water retention. Granular structure increases soil resistance against erosion and increases microbial populations in soils. Therefore, identifying the salinity and organic matter changes of soils are the first and most important step in the proper management and utilization of the land. Direct

field observations and remote sensing Techniques are some methods to assess soil characteristics. Considering time and cost factors, soil degradation studies in large areas, using remote sensing and GIS seems to be a more effective technique (Gao and Liu 2008; El-Baroudy and Moghanm 2014).

Remote sensing by providing updated information is a superior and efficient technique for the study of environmental changes and management of natural resources. In order to study and determine the rate and trend of changes, a wide range of temporal and spatial data sets is required. Measures are now taken to monitor and assess soil salinity in the world including Iran, and many studies have been done in this regard. Arekhi and komaki (2015) investigated land cover and landscape change dynamics by using satellite (RS) and GIS. They found a decrease in poor rangeland with an increase of agricultural land and sand plate areas. Hakimzadeh Ardakani *et al.* (2017) investigated the effects of land use changes on trend of desertification by using Landsat images

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they used ETM⁺ data. Dwivedy and Ramana (2003) to classify the gullies used LISS_III data. Running *et al.* (2005) used three different classification methods using simulated spectral data, for mapping land cover. The results showed that the maximum likelihood method is highly efficient and effective in mapping land cover.

Givei *et al.* (2014) investigated soil salinity monitoring by using data of ASTER satellite in 7 years (2003 to 2010) and concluded that the surface of saline area decreased after this period. Abdelfattah *et al.* (2009) used Landsat ETM⁺ data from the years 2000 and 2002 and examined the soil salinity that was a huge concern in the coastal area of the United Arab Emirates. Taghizadeh-Mehrjardi *et al.* (2014) used Landsat 7 ETM⁺ data, apparent electrical conductivity (ECa), an electromagnetic induction instrument (EMI), and a geomorphologic surfaces map to derive the relationships between ECe (from soil surface to 1 m) and the auxiliary data, with regression tree analysis. In general, results showed that the ECa surfaces are the most powerful predictors for ECe at three depth intervals (i.e. 0–15, 15–30 and 30–60 cm). Liu *et al.* (2008) studied the soil salinity changes in Mongolia region, China, using Landsat satellite images. Their findings showed that remote sensing is a useful tool to study soil salinity and to improve soil and water management.

Joshi *et al.* (2005) used the IRS-1C satellite images to study the land use changes in the valley area of Nubra, India. Fallah *et al.* (2014) examined forest stand types classification by using Spot data.

Coppin *et al.*, (2004), in their review article said that less than one pixel error is acceptable for geometric correction. The results indicate that in this study, thermal bands are more efficient in the choice of the best model and it is corresponding with the results obtained by Garcia *et al.*, (2008). Fathizad *et al.*, (2018) evaluated desertification in Yazd-Ardakan plain using remote sensing technique. Results showed that during the period of 1986–2016, the area of agriculture lands and poor pasture area were decreased by 5696 and 579888 hectares (1.18% and 12.01%) respectively, while the barren, residential and the sand dunes were exposed to an increasing trend of 2419, 35454 and 457 hectares (5.16, 7.34 and 0.09) respectively.

Yong-Ling *et al.*, (2010) reported that the spectral measurements of saline soil samples collected from the Yellow River Delta region of China conducted in laboratory and hyperspectral data acquired from an EO-1 Hyperion sensor to

quantitatively map soil salinity in the region. A soil salinity spectral index (SSI) constructed from continuum-removed reflectance (CR-reflectance) at 2 052 and 2 203 nm, to analyze the spectral absorption features of the salt-affected soils. There existed a strong correlation $r = 0.91$ between the SSI and soil salt content (SSC). Then, a model for estimation of SSC with SSI established using univariate regression and validation of the model that yielded a root mean square error of 0.986 and r^2 of 0.873. The model was applied to a Hyperion reflectance image on a pixel-by-pixel basis and the resulting quantitative salinity map was validated successfully with root mean square error of 1.921 and $r^2 = 0.627$. These suggested that the satellite hyperspectral data had the potential for predicting SSC in a large area. However, leaching will reduce the amount of salt in the soil surface, but the amount of sodium adsorption ratio (SAR) is unchanged and the soil will become alkaline.

Ting-Ting Zhanga *et al.* (2015) showed that the quality of the enhanced vegetation index (EVI) time series data were improved by the Savitzky–Golay filter, which could provide more accurate thresholds of phenological stages than the empirical definition. The seasonal integral of EVI (EVI-SI) extracted from the smoothed EVI time series profile was verified as the best indicator of the degree of soil salinity. Additionally, the correlation of EVI-SI and soil salinity was highly dependent on land cover heterogeneity, and the ranges of correlation coefficients were as high as 0.59–0.92. EVI-SI was linearly correlated with ECe in cropland with a high model fit $r^2 = 0.85$. The relationship of EVI-SI and ECe fit best with a binomial line and EVI-SI was able to explain 70% of the variance of ECe. Despite the poor fit of the linear regression model in mixed sites limited by spatial resolution $r^2 = 0.32$, MODIS time series VI data, as well as the extracted seasonal parameters, still show great potential to assess large-scale soil salinization.

Matinfar *et al.*, (2007), reported that for classification of arid soils in Aran and Bidgol, they used the LISS-III satellite data.

Metternicht and Zinckb (2003) reviewed that Soil salinity caused by natural or human-induced processes is a major environmental hazard. The global extent of primary salt-affected soils is about 955 M ha, while secondary salinization affects some 77 M ha, with 58% of these in irrigated areas. Nearly 20% of all irrigated land is salt-affected, and this proportion tends to increase in spite of considerable efforts dedicated to land

reclamation. This requires careful monitoring of the soil salinity status and variation to curb degradation trends, and secure sustainable land use and management. Multitemporal optical and microwave remote sensing can significantly contribute to detecting temporal changes of salt-related surface features. Airborne geophysics and ground-based electromagnetic induction meters, combined with ground data, have shown potential for mapping depth of salinity occurrence. The agricultural history of the world shows that regardless of the balance of salt, agriculture is not stable, especially in arid and semi-arid areas. So, by studying the salinity in different times, the trend of salinity progression can be found in saline areas.

The purpose of this research is monitoring soil salinity and organic matter in agricultural land of Harat plain, plain in Yazd province of

Iran. The results (salinity indices and soil organic matter) compared to true ground data created by the field trip during the years from 2008 to 2012.

2. Materials and Methods

2.1. Study area

The study area is located in the central of Iran and at a distance of 240 kilometers south of Yazd province, Harat plain, is located between longitudes 54° 21' to 55° 38' East and latitudes 29° 47' to 30° 12" north (Fig. 1). Average annual temperature and average rainfall is 18.7 °C and 87.5 mm, respectively. According to the Domarten method, the climate of the area has been determined as a dry cold to highly dry cold (Vahdati, 2014).

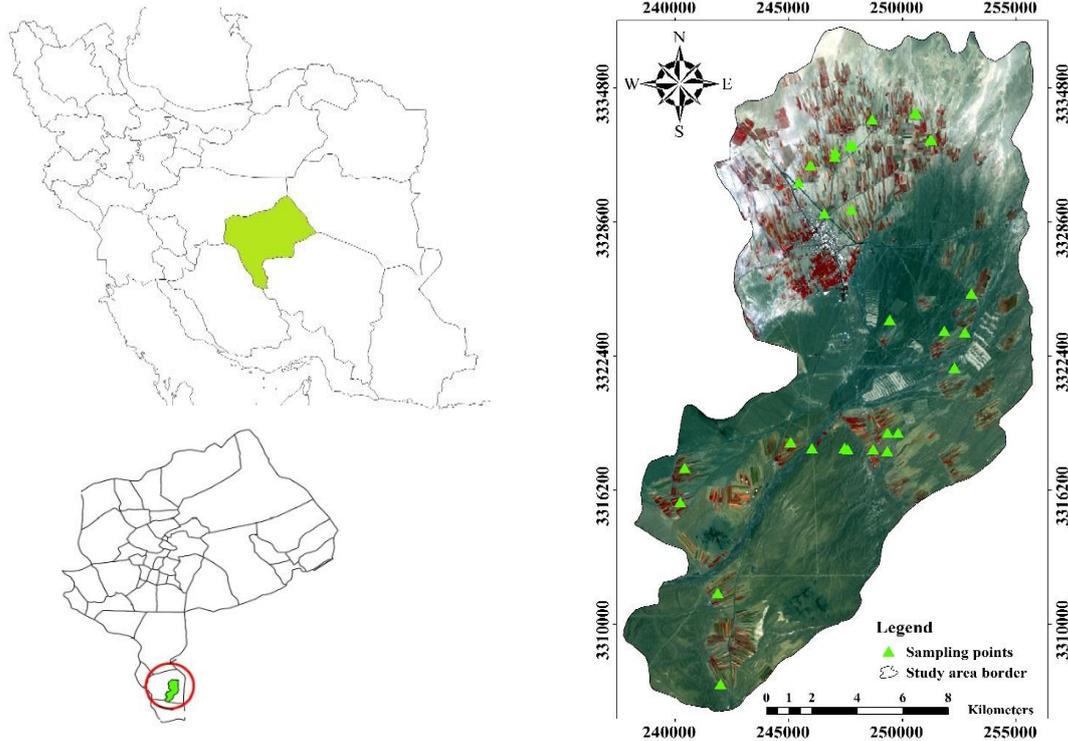


Fig. 1. Geographical location of Harat region, located in Yazd province, central part of Iran

2.2. Research Methodology

To detect the changes in soil salinity and organic matter in the agricultural lands, the LISS III data of 30 October 2008 and 5 November 2012 used. Also, two indices of (EC) and (OM), were used to monitor the impact of agricultural activities on the sampling points with the same geographical location, in 2008

and 2012. These points were under wheat and barley cultivation.

In order to monitor, at first, the ENVI5.1 software was used to do the preprocessing operations include finding a proper band combination for appropriate initial interpretation of images, separating the study area borders and geometrically correcting of 2012 image. In this study, the combination of original bands 1, 2 and 3 used. Image to image geometric

correction method used in which the image 2008 selected as the reference image and the image 2012 chosen as the function image. Then, using 33-ground control point on the reference image and the corresponding points in the function image, the Quadratic equation and nearest neighborhood method, the geometric correction of the image 2012 with RMSE of 0.48 pixels was done. The spectral image processing on both images, samples were matched with the whole bands of original and false color composite images and the pixel value of them were extracted. Then, using SPSS software and Stepwise test, regression models and the coefficients between each component of EC and OM with all of the bands, indicators, spectral ratios and principal components were determined. After preprocessing operations, to assess changes in soil indices (EC and OM), the images were classified using supervised classification method and maximum likelihood algorithm. The method requires the training data or given pixels for each class which are

separately defined. To enter training data to classification system, the results of field experiments used. Samples taken from a depth of 0 to 30 cm from 33 places. By doing tests on soil samples in the laboratory, soil salinity (EC) was determined using EC meter, and the results classified according to the American classification method. The organic matter content (OM) was determined using Walkley-Black Method. The accuracy of classified images was evaluated using control points and calculating the kappa coefficient and overall accuracy. Finally, the changes map do for the desired period (2008 - 2012).

3. Results and Discussion

3.1. Laboratory analyses of soil Samples

The Comparison of the experimental results such as pH, salinity and soil organic matter indicators in the period of 2008-2012 is show in Figures 2 to 4.

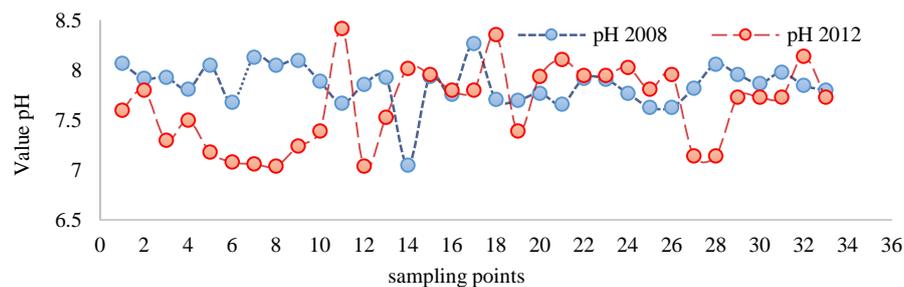


Fig. 2. Charts of the soil pH changes in 2008 and 2012

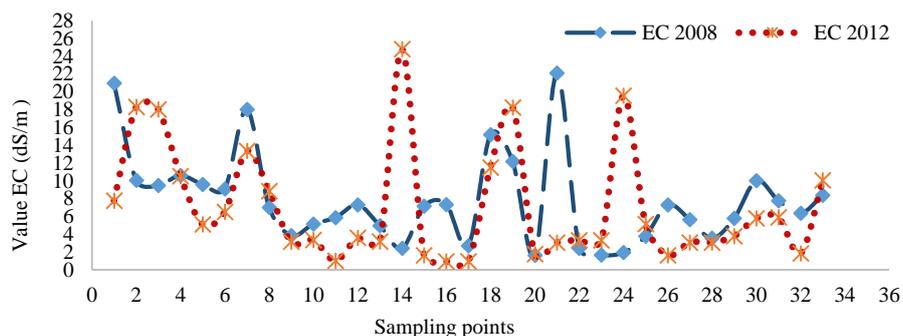


Fig. 3. Charts of the soil salinity (EC) changes in 2008 and 2012

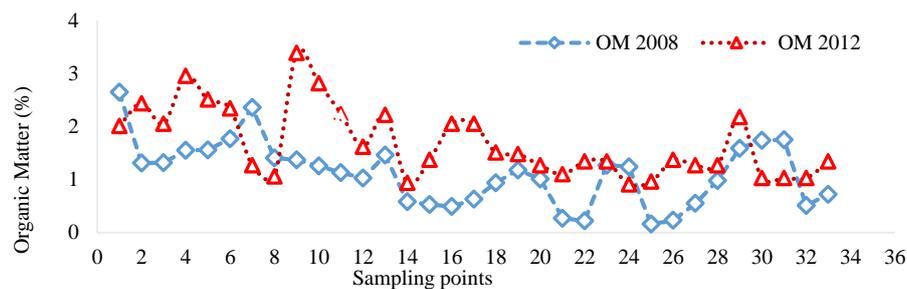


Fig. 4. Charts of the soil organic matter (OM) changes in 2008 and 2012

As showed in Fig. 2 in the most parts of sample points soil pH increased during 2008 to 2012. These results indicate that agricultural activities and irrigation in the region are on increase in pH and in some places, this increase is quite impressive. It could be due to different water resources and agricultural wells for irrigation. In general, it can be said that irrigation of agricultural lands within four years increased basic ions such as sodium in soil.

According to Fig. 3, soil salinity shows different trends in different parts over the study years. In the most parts of agricultural lands, irrigation has caused reduction in soil salinity, but in 6 points soil salinity increased. As mentioned above, different water sources with different water qualities could cause these different trends in soil salinity although in the most parts of study area, soil salinity has been decreased during the investigation period (2008-2012).

The obtained results show that agricultural activities has been increasing soil organic matter in the most of the soil samples in the study area from 2008 to 2012 (Fig. 4).

Except for 6 points, the other soil samples show a substantial increase in the rate of soil organic matter during the period of this Investigation and this trend indicated that

agricultural activities have increased soil organic matter especially in desert region.

3.2. Classification of the soil salinity and organic matter

The classified map of soil salinity and organic carbon (EC, OM) are shown in Figures 5 to 8. Classification accuracy and Kappa coefficient of an EC map of 2008 were 82% and 0.73, respectively, and 84% and 0.7 for the image of 2012, respectively. Classification accuracy and Kappa coefficient of an OM map of 2008 was 85.5% and 0.76, respectively, and 84% and 0.74 for the image of 2012, respectively. The results show that the accuracy of most of spectral maps (classified maps) is over 70%, which is indicative of the efficacy of IRS - LissIII satellite images for the soil science studies and classification of soil salinity ranges. According to Figures 3, 4 and 5 and comparing the test results, it can conclude that soil pH value increased in most regions.

3.3. Regression models and the coefficients between each component of EC and OM

In addition, a two-variable regression equation was used to verify the accuracy of the Produced maps of soil salinity and organic matter (EC, OM) in a given period (Figs. 9 -12).

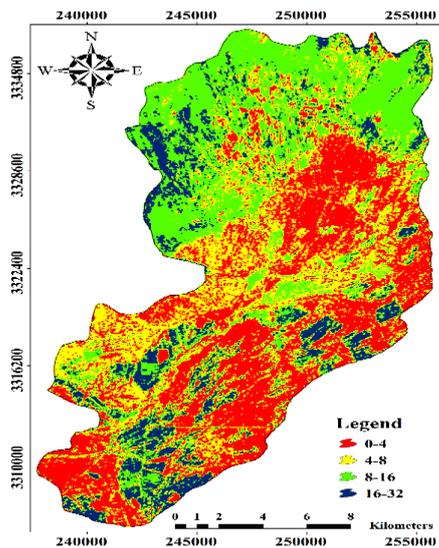


Fig. 5. Soil salinity classification map (EC map) related to the samples of the year 2008

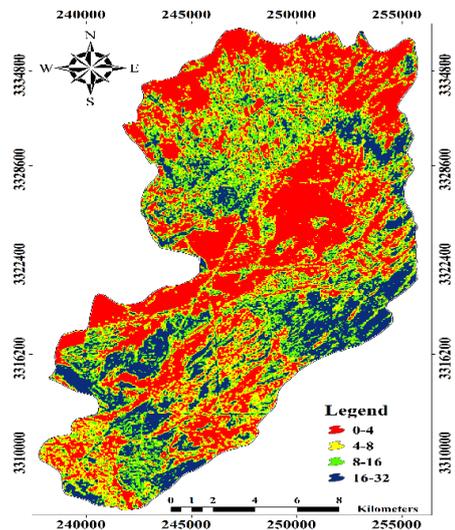


Fig. 6. Soil salinity classification map (EC map) related to the samples of the year 2012

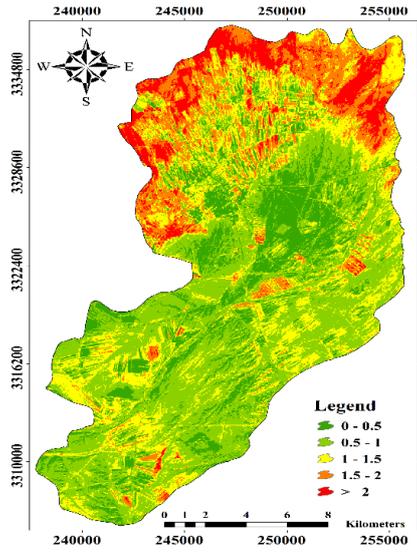


Fig. 7. Soil organic matter classification map (OM map); related to the samples of the year 2008

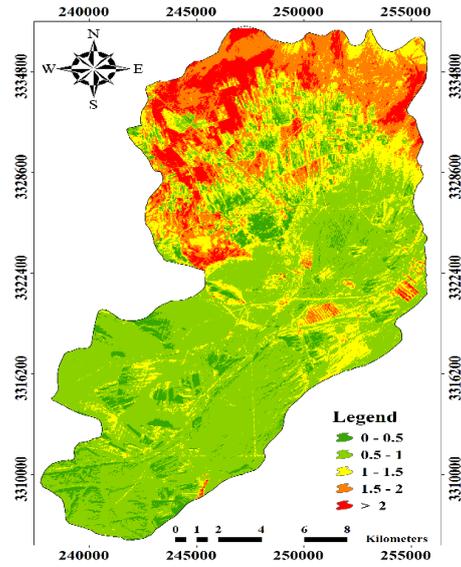


Fig. 8. Soil organic matter classification map (OM map); related to the samples of the year 2012

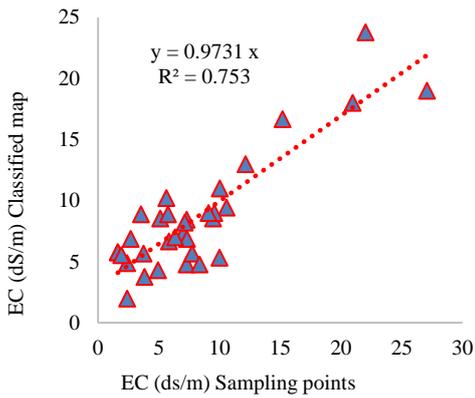


Fig. 9. The relationship between salinity of the sampling points and points of the classified map of the year 2008

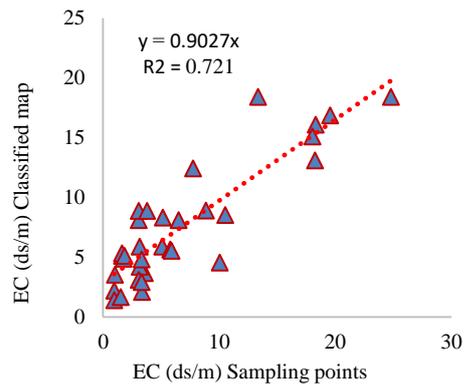


Fig. 10. The relationship between salinity of the sampling points and points of the classified map of the year 2012

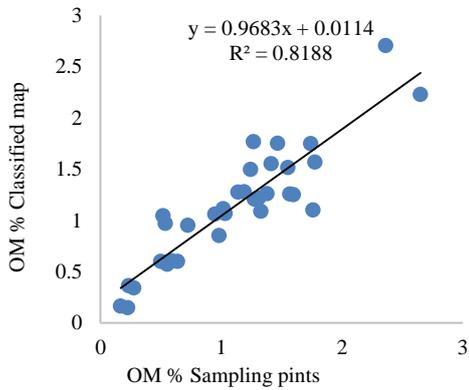


Fig. 11. The relationship between soil organic matter of the sampling points and points of the classified map of the year 2008

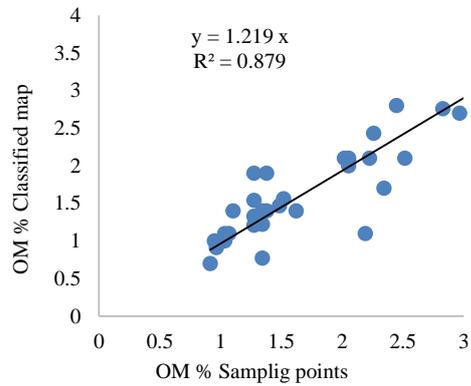


Fig. 12. The relationship between soil organic matter of the sampling points and points of the classified map of the year 2012

For evaluation the relationship between two sources of data, the correlation coefficients (r^2) between soil salinity and organic matter at 2008 and 2012 years in sample points and that evaluated by classified map from satellite data were calculated by Pearson method (Figs 9-12).

The results showed that the range of correlation coefficients (r^2) were acceptable (0.721 to 0.879). Therefore, these results showed the maps

that prepared by satellite data could be used with desirable accuracy.

3.4. Changes map of soil salinity and soil organic matter (2008 - 2012)

The change map of soil salinity and soil organic carbon (EC, OM) during the given period presented in Figures 13 and 14. There are five classes, including increased, decreased, slightly increased, slightly decreased and lands and areas without any significant changes in each map.

4. Conclusion

This study was carried out in order to monitor the soil salinity using remote sensing data in Harat plain (Yazd province), in the period of 2008-2012. The IRS - LissIII data used for soil monitoring and mapping the soil salinity and organic matter changes. According to the research done in the field of geometric correction, it can be concluded that the image which has been used in this study was geometrically correct with high precision. The error of image classification was less than half pixel so it is appropriate for georeferencing.

The results showed that the accuracy of most of spectral maps (classified maps) is over 70%, which is indicative of the efficacy of IRS-LissIII satellite images for the soil science studies and classification of soil salinity ranges. According to Figs 3, 4 and 5 and comparing the test results, it can be concluded that soil pH value increased in most regions. The changes in soil salinity were not regular and there was a reduction in some areas and increment in some places. The number of points with decreased salinity is higher than the points with increased salinity. Soil organic matter increased in most of the places while in some areas it accompanied by a huge increase. It was because of the addition of organic matter (manure, green manure) and fertilizers to agricultural lands and increment in activity of soil microorganisms that provide the conditions for increasing the soil organic matter. It can be stated that the increase in organic

matter improves soil structure and the increasing in the porosity and aeration increases the infiltration. Increase the area under cultivation also increased the organic matter content, which not only has a negative impact on agricultural lands but also leads to desertification. According to Figure 8, acceptable correlation coefficient (0.77 and 0.83) between ground data and satellite images, and with regard to the fact that the major crops of the study area are wheat and barley so the IRS satellite images are proper for accurate interpretation. The information of grass covers due to its rapid growth gained precisely by the IRS satellite images. However, in many studies, it has been stated that there was not any relationship between soil salinity and satellite data (Wood *et al.*, 2004; El-Haddad and Garcia, 2005).

Soil salinity values (EC) have irregular changes in the period of 2008-2012. According to the classification map of soil salinity index, the frequency of lands with decreased salinity and without changing is high, indicating decreasing salinity in the area that could be due to the high quality of irrigation water and salt leaching. Of course, it would lead to accumulation of salt in the sub horizons in the coming years and disrupt the quantitative and qualitative growth of the agricultural products.

Soil salinity values are variable between 1.6 to 22.4 dS/m, thus the accuracy of soil salinity maps that have been prepared with ground operations, will decrease. Gutierrez and Johnson (2010) in their study used six Landsat scenes over El Cuervo, a closed basin adjacent to the middle Rio Conchos basin in northern Mexico, to show temporal variation of natural salts from 1986 to 2005. Natural salts were inferred from ground reference data and spectral responses. The results of land cover classes showed a relationship between climatic drought and areal coverage of natural salts. When little precipitation occurred three months prior to the capture of the Landsat scene, approximately 15%–20% of the area was classified as salt. The basic maps play an important role in such maps. However, with the increasing importance of precision agriculture as a modern science, the need for raster maps has increased and satellite information is the best tool in this regard. Therefore, preparation of accurate salinity maps using field information is the best way to use satellite information and this information can significantly increase the accuracy of the final map.

References

- Arekhi, S., B. Komaki, 2015. Detecting and assessing desertification landscape metrics in Gis environment (Case study: Ain-e-Kosh region, Iran). *Environment Resources Research*, 3; 121–137.
- Abdelfattah, M., Sh. Shahid, Y. Othman, 2009. Soil salinity mapping model developed using RS and GIS: A case study from Abu Dhabi, United Arab Emirates. *European Journal of Scientific Research*, 3; 342-351.
- Coppin, P., I. Jonckheere, K. Nackaerts, B. Muys, 2004. Digital change detection methods in ecosystem monitoring: a review. *International Journal of Remote Sensing*, 25; 1565-1596.
- Dwivedi, R.S., K.V. Ramana, 2003. The delineation of reclamative group of ravines in the Indo Gangetic alluvial plain using IRS-1D LISS-III data. *International Journal of Remote Sensing*, 51; 4347-4357.
- El-Baroudy, A. A., F.S. Moghann, 2014. Combined use of remote sensing and GIS for degradation risk assessment in some soils of the Northern Nile Delta, Egypt. *The Egyptian Journal of Remote Sensing and Space Sciences*, 17; 77-85.
- Fathizad, H., M. A. Hakimzadeh Ardakani, R. Taghizadeh Mehrjardi, H. Sodaiezadeh, 2018. Evaluating desertification using remote sensing technique and object-oriented classification algorithm in the Iranian central desert. *Journal of African Earth Sciences*, 16; 1-24. doi: 10.1016/j.jafrearsci.2018.04.012.
- Fallah, A., S. Kalbi, S. shataee, 2014. Forest stand types classification using tree based algorithms and Spot-HRG data. *Environment Resources Research*, 29; 31–45.
- Fernandez-Buces, N., C. Siebe, S. Cram, J. Palacio, 2006. Mapping soil salinity using a combined spectralresponse index for bare soil and vegetation: A case study in the former lake Texcoco, Mexico. *Journal of Arid Environments*, 65; 644–667.
- Gao, J., Y. Liu, 2008. Mapping of land degradation from space: a comparative study of Landsat ETM⁺ and ASTER data. *International Journal of Remote Sensing*, 29; 4029-4043.
- Garcia, M., C. Oyonarte, L. Villagarcia, S. Contreras, F. Domingo, 2008. Puigdefabregas, JMonitoring land degradation risk using ASTER data: The non-evaporative fraction as an indicator of ecosystem function. *Remote Sensing of Environment*, 112; 3720–3736.
- Giveii Ashraf, Z., M. A., Hakimzade, M. Zare, Z., Ebrahimi Khusfii, K., Dashtakian, 2014. Monitoring of soil salinity using ASTER satellite data to evaluate desertification in the Marvast plain, Yazd province, Rangeland and Watershed management, *Iranian Journal of Natural Resources*, 67; 603- 616
- Gutierrez, M., E. Johnson, 2010. Temporal variations of natural soil salinity in an arid environment using satellite image. *Journal of South American Earth Sciences*, 30; 46–57.
- Hakimzadeh, M.A. 2014. Assessment of desertification risk in agricultural land in south of Iran. *International Journal of Advanced Biological and Biomedical Research*, 2; 669 – 681.
- Hakimzadeh Ardakani, M.A., F. Cheshm Berah, M.H. Mokhtari, 2017. Investigating the Effects of Land Use Changes on Trend of Desertification Using Remote Sensing (Case Study: AbarkoohPlain, Yazd, Iran). *Journal of Rangeland Science*, 7; 348-360.
- Jian-li, D., W. Man-chun, W.T. Tiyip, 2011. Study on Soil Salinization Information in Arid Region Using Remote Sensing Technique. *Journal of Agricultural Sciences in China*, 3; 404-411.
- Joshi, P.K., G.S. Rawat, H. Padaliya, P.S. Roy, 2005. Land use/land cover identification in an alpine and arid region (Nubra valley, Ladakh) using satellite remote sensing. *International Journal of Remote Sensing*, 3; 371-380.
- Liu, H., CH. Zhou, W. Cheng, E. Long, R. Li, 2008. Monitoring sandy desertification of Otindag sandy land based on multi-date remote sensing images. *Acta Ecologica Sinica*, 2; 627–635.
- Matinfar, H.R., Alavipanah, S.K., Maleki, A., A. Karimy, 2007. Separability of aridic soils by means of LISS-III sensor data: a case study in the Aran-Bidgol. *Agricultural Research: Water, Soil and Plant in Agriculture*, 4; 23-37.
- Running, S. R., L. L. Pierce, E. R. Hunt, 2005. A remote sensing based vegetation classification logic for global remote land cover analysis. *Ecological Monographs*, 67; 251-271.
- Metternicht, G.I, J.A. Zinckb, 2003. Remote sensing of soil salinity: potentials and constraints. *Remote Sensing of Environment*, 85; 1–20.
- Taghizadeh-Mehrjardi, R., F. Minasny, B. P. Sarmadian, 2014. Malone, Digital mapping of soil salinity in Ardakan region, central Iran. *Geoderma*, 213; 15–28.
- Ting-Ting Zhanga, Jia-Guo Qib, Yu Gaoa, Zu-Tao Ouyangb, Sheng-Lan Zengc, Bin Zhaod, 2015. Detecting soil salinity with MODIS time series VI data. *Ecological Indicators*, 25; 480–489.
- Vahdati, A.R., 2014. Monitoring of soil salinity using remote sensing data the specific management of agricultural land in plain Herat Yazd. M.Sc. thesis, Department of Desert Management, Faculty of Natural Resources, Yazd University, Iran.
- Yu, R., T. Liu, Y. Xu, C. Zhu, Q. Zhang, Z. Qu, X. Liu, C. Li, 2010. Analysis of salinization dynamics by remote sensing in Hetao Irrigation District of North China *Journal of Agricultural Water Management*, 97; 1952–1960.
- Yong-Ling W., G. Peng, A. Z. Zhi-Liang, 2010. Spectral Index for Estimating Soil Salinity in the Yellow River Delta Region of China Using EO-1 Hyperion Data. *Pedosphere*, 20; 378–388.