Volume 14, Issue 4, 142429 (1-8)

Journal of Rangeland Science (JRS)

https://dx.doi.org/10.57647/j.jrs.2024.1404.29

Assessing intensity of desertification and land rehabilitation using the change vector analysis method (Case study: Dehshir Plain, Yazd province, Iran)

Azam Abolhasani[1], Hassan Khosravi [1,*], Esmail Heydari Alamdarloo [1], Saeed Barkhori [2,*]

[1]*Department of Reclamation of Arid and Mountainous Regions, Faculty of Natural Resource, University of Tehran, Tehran, Iran.*
[2]*Faculty of Natural Resources, Jiroft University, Jiroft, Iran.*

[*]**Corresponding author:** hakhosravi@ut.ac.ir; barkhori.ss@ujiroft.ac.ir

Research and Full Length Article

Received:
21 June 2022
Revised:
17 September 2023
Accepted:
31 October 2023
Published online:
15 October 2034

Abstract:

Desertification is one of the main ecological and environmental problems in Iran. It is remarkably urgent to monitor and assess this phenomenon and its impact on ecosystem components such as vegetation covers to prevent and combat desertification. This study aimed to evaluate the Change Vector Analysis (CVA) method's efficiency in assessing and monitoring desertification in Dehshir Plain, Yazd province, central Iran. For this purpose, the imagery of Landsat 5 from 1994 to 1998 (T1) and Landsat 8 from 2014 to 2018 (T2) were selected in June and July period on the Google Earth Engine platform. Then, the Bare Soil Index (BSI) and Normalized Difference Vegetation Index (NDVI) were calculated for the two periods. The direction and the strength of changes in NDVI and BSI were determined based on the CVA method. The results showed that 27.27% and 38.65% of the region surfaces were in degraded and rehabilitated states, respectively. The severity of degradation was higher in the central and northern parts of the study area. Adversely, rehabilitation has increased in the south, west, and east parts of the region. The results of CVA and field reality showed that this method could well reveal changes in ecosystem components over time, which is due to the comparison of two different periods using land cover indicators such as plants and soil. Our finding suggested that the CVA was an appropriate method for monitoring and assessing the desertification phenomenon and determining the area under degradation or rehabilitation in arid regions.

Keywords: Degradation; NDVI; BSI; Change Direction; Change Strength

Introduction

Desertification, which was considered as a major global issue at the United Nations Conference on Desertification in Nairobi, Kenya, in 1977, is a significant challenge in many countries especially developing countries (Silakhori, 2014). The desertification process has threatened more than 785 million people in arid regions (Sadeghiravesh et al., 2014). Desertification has affected 110 countries globally, with more than 1 billion populations (Marinică and Marinică, 2014). Many global efforts have been made to combat this phenomenon during the past decades. Desertification is defined as reducing land productivity resulting from natural factors or inappropriate human activities, including water and wind erosion, vegetation degradation, water resource degradation, salinization, etc. (Vali et al., 2015). Desertification leads to ecosystem degradation and a decrease in the performance of biological production (Davari et al., 2017). According to the UNCCD, desertification is defined as a process of land degradation in arid, semi- arid, and dry sub- humid regions due to various factors, including climatic variations and human activities (UNCCD, 2012). For combating this phenomenon, monitoring and prioritizing the areas with a high risk of desertification are crucial and essential stages (Amiraslani and Dragovich, 2011).

Desertification has gradually affected half provinces in Iran (Amiraslani et al., 2018). So, determining the new methods for assessing desertification and its causes has high priority in Iran, in which 85% of the country's surface is under arid, semi- arid, and hyper- arid climates (Bakhshandeh Mehr and Soltani, 2014; Hakimzadeh Ardakani et al., 2017). Due to the great extent and the dynamic nature of phenomena such as land degradation and desertification, human attention has been focused on using new technologies to assess and monitor these phenomena. On the other hand, combating and controlling desertification in an area has to be based on current and past situations of desertification (Sadeghiravesh et al., 2021). One of the most important technologies is remote sensing, which has an essential role in determining and monitoring desertification of land degradation on local, regional, and global scales (Rahimi et al., 2013).

Change detection is a process that evaluates spatial variations of different phenomena (e.g., plant and bare soil cover), prys, and posts a specific factor resulting from natural or anthropogenic factors using multi- temporal satellite imagery. This process includes various methods such as Gramm- Schmidt, Principle Component Analysis, Biophysical Parameter Method, and Change Vector Analysis (CVA). Among change detection techniques, CVA can provide spectral change information regarding the change strength and direction (Allen and Kupfer, 2000). Generally, the CVA method is an effective procedure for change detection and land cover change (Khiry et al., 2015). This method is a multivariate technique for pixel- by- pixel analysis of bands or spectral indices that are obtained by placing them on two axes of a Cartesian plane and can evaluate changes between two different times (Lorena et al., 2002; Dawelbait and F., 2012).

Many studies have been conducted using CVA for assessing land degradation, desertification, vegetation changes, etc. in different parts of the world. Khiry et al. (2015) used CVA to analyze and map desertification processes in an arid and semi- arid region, North Kordofan State, Sudan. Their results showed that the CVA and Landsat data appeared to be a reliable and low- cost technique for analyzing and mapping desertification processes in Sudan's arid region. Becerril-Pina et al. (2016) integrated several remote sensing techniques for monitoring desertification in a semi- arid region of the central Mexican plateau. Their results indicated that 48.3% of land use corresponded with agricultural areas; 2.7% of the district did not present any degree of desertification, while 49% gave the following degrees of desertification: 5.5% extreme, 10.9% severe, 18.9% medium, and 13.7% low. Lamchin et al. (2016) assessed land cover change and desertification using remote sensing technology in a local region of Mongolia. They concluded that the desertification of the area was increasing annually. Vorovencii (2017) assessed the desertification risk in Southwest of Romania from 1984 to 2011 using the CVA technique. Its results indicated that both anthropogenic and climatic factors had affected the desertification of the region. Shao et al. (2018) monitored the grassland change in the Qinghai- Tibetan Plateau in Aba County, China, using the CVA method and concluded that vegetation re- growing has occurred since 2003.

This paper evaluates the CVA method efficiency and presents a new approach for assessing and monitoring desertification in Dehshir Plain, Yazd province, Iran which faced excessive droughts in recent years and has been exposed to desertification. Although several studies related to vegetation cover have been done using the CVA method in different parts of the world and Iran, there is no comprehensive study about the efficiency of this technique for assessing desertification in the Dehshir Plain, Yazd province, Iran. Therefore, the results of this study can be useful for decision-makers in combating desertification and land degradation in the study area.

Materials and Methods

Study area

The study area, Dehshir Plain, is located between the southern slopes of Shirkooh Mountain and Abarkooh Plain in Yazd province, Iran. The total area of the region is 3233 km^2. Based on the isohyetal map, the annual precipitation is less than 50 mm in the southwest and more than 300 mm in the north and northeast (Iran Meteorological Organization). Most of the rainfall occurs in the winter. Also, the mean annual temperature of the region is between 8-16°C. Two main occupations are agriculture and animal husbandry, but many agricultural lands have been abandoned in recent years due to drought occurrence. The location of the study area is presented in Figure 1.

Methodology

In this research, the CVA method was used to determine the desertification changes. As every vector has two dimensions including direction and strength, the results of this method provide the direction and strength of changes (Figure 2). According to the investigations and consultation with experts in the study area, April to July period was selected to evaluate the changes. First, 32 Landsat 5 images during the years 1994-1998 (T1) and 32 Landsat 8 images during the years 2014-2018 (T2) were selected from April to July. Finally, images with cloud cover below 1% were considered for assessing changes. Then the bare soil index (BSI) and normalized vegetation difference index (NDVI) were calculated for each selected image, and the average of both indices was computed in both periods. In arid regions, soil and vegetation degradation due to climatic factors or human activities is an index for desertification (Karnieli et al., 2014). Regarding this issue, we used two indices of NDVI (Normalized Difference Vegetation Index) and BSI (Bare Soil Index) to assess desertification based on the CVA method.

NDVI; representing vegetation parameters such as green biomass (Zaady et al., 2007); has been used in many studies in arid and semi- arid areas (Abolhasani et al., 2022; Heydari Alamdarloo et al., 2018; Khosravi et al., 2017). The NDVI is based on the fact that the chlorophyll in the plant structure can absorb red light, and the mesophyll

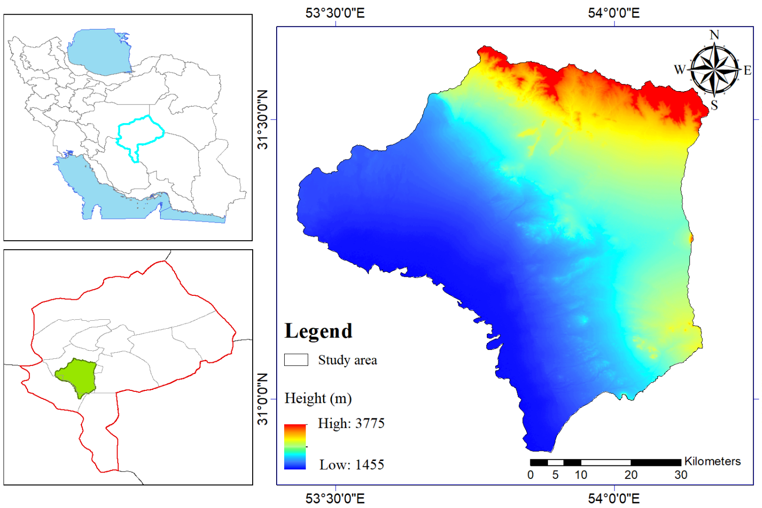

Figure 1. The location of the study area.

layers of the leaf reflect near- infrared light (Rafiei Sardooi et al., 2021). The BSI index is also used to assess the desertification processes related to the soil criteria (Rikimaru et al., 2002; Xiao et al., 2006). The two indices of BSI (Fitrianto et al., 2018) and NDVI were obtained based on the following equations.

$$NDVI = \frac{(NIR - R)}{(NIR + R)} \quad (1)$$

$$BSI = \frac{(SWIR + R) - (NIR + B)}{(SWIR + R) + (NIR + B)} \times 100 + 100 \quad (2)$$

where:
NIR= Near-infrared,
R= Red
SWIR= are, and short-wave infrared bands.
NDVI varies between 1 and -1; the *NDVI* ratio closer to 1 shows there is more vegetation.
BSI varies between 0-200; the BSI ratio relative to 200 indicates more bare soil (Fitrianto et al., 2018).
Using *NDVI* and *BSI* indices, the strength of change (Equation 3) and the direction of change (Equation 4) were determined based on the CVA method in GIS software (Becerril-Pina et al., 2016).

$$M = \sqrt{(NDVI_2 - NDVI_1)^2 + (BSI_2 + BSI_1)^2} \quad (3)$$

$$\tan\theta = \frac{(BSI_2 - BSI_1)}{(NDVI_2 - NDVI_1)} \quad (4)$$

where:
$NDVI_1$ and $NDVI_2$ show the $NDVI$ in the first and the second periods, respectively.
BSI_1 and BSI_2, bare soil indices, are related to the first and second periods.
M is the strength of changes, and $\tan\theta$ is the gradient of changes. θ shows the direction of changes so that it's the amount between 90 to 180 indicates the increase of vegetation (re- grow), and between 270 to 360 shows the growth of bare soil (degradation). Also, 0-90 and 180-270 show the situation's stability or no change in vegetation or bare soil condition (Lorena et al., 2002). On the other hand, the areas where $\tan\theta$ had positive values been considered unchanged, where $\tan\theta$ and Δ NDVI had negative values found under degradation, and where $\tan\theta$ had negative values. ΔNDVI had positive values that were considered under rehabilitation. Then, each area was classified into three classes using the natural break method in ArcGIS. This method minimizes the difference between data in each category and maximizes the difference among different classes. In this

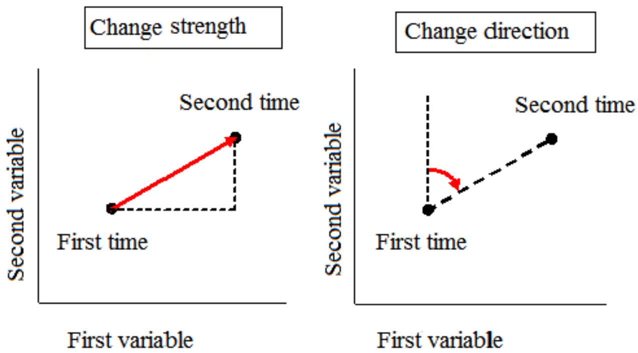

Figure 2. The components of the Change Vector Analysis (CVA) method (Eastman, 2015).

research, ArcGIS var. 10.6 was used for CVA calculation and classification. The stages of this study are shown in a flow chart (Figure 3).

Results

The changes in BSI and NDVI during the two periods are shown in Figure 4. The amount of the BSI index was high in the northern part of the region, but from the north to the southern parts of the area, its amount decreased during the two periods. The amount of NDVI was high in the north, northeast, east, and southwest parts of the region (Figure 4). After determining the changes in BSI and NVDI indices, the direction and the strength of changes were assessed based on the CVA analysis using ArcGIS 10.6. Based on the results, the strength of changes was higher in the north, northeast, south, and southwest parts of the region (Figure 5), which may be due to the area's degradation or rehabilitation. The direction of changes is illustrated in Figure 6. There are the regions under the degradation and rehabilitation process and also the regions with no changes. The degradation intensity was higher in the northern and central parts. Also, some areas in the east and the southeast had been degraded (Figure 6).

The area percentage of the different conditions is shown in Figure 7. Based on the results, 38.65% of the region was categorized in the rehabilitation condition, 34.08% had no changes during the studied period, and 27.27% of the area was under degradation.

Figure 8 demonstrates the combination of the intensity of rehabilitation and degradation and the direction of changes (rehabilitation or degradation) in the region. The strength of changes was higher in the north and northeast than in other parts of the area. In most of these parts, the severe and medium degradation classes were consistent with drainage networks, the margins of rivers, valleys, and villages. Toward the south and southeast of the region, the intensity of degradation has reduced. Some parts of the central and southeast of the area have also degraded. The intensity of rehabilitation was medium in the north, northeast, northwest, and east of the region, and it has increased significantly in the west.

Based on the percentage of different classes' areas obtained from the Natural Break method. In the regions under rehabilitation, the medium-intensity rehabilitation class had the most surface (22.44%). The low-intensity rehabilitation class included 15.48% of these regions, and the high-intensity rehabilitation class included 0.73% of the regions. Regarding degradation, the low-intensity, medium- intensity, and high- intensity classes have included 26.31%, 0.71%, and 0.25% of the regions, respectively (Figure 9).

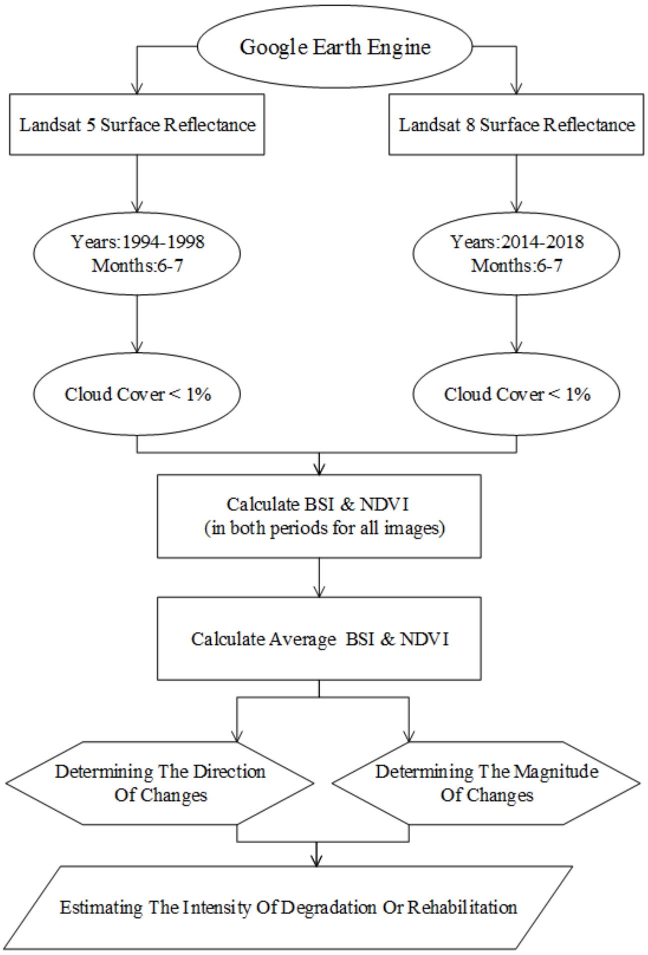

Figure 3. Flow chart of the study.

2008-9996[https://dx.doi.org/10.57647/j.jrs.2024.1404.29]

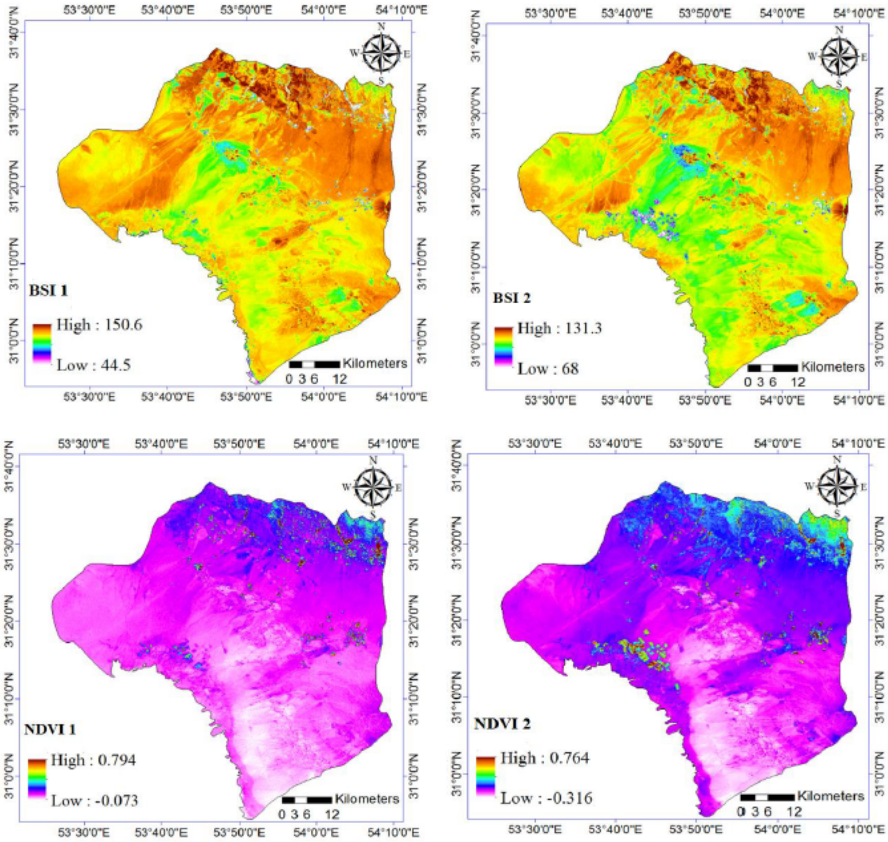

Figure 4. The changes in *BSI* and *NDVI* during the two periods.

Discussion

Desertification is a significant ecological problem worldwide which causes the loss of the productivity of the land due to human activities or environmental factors. Detecting spatial variations of desertification can help managers and decision-makers in combating this hazard. As mentioned in the literature, CVA can provide spectral change information regarding the change strength and direction of different phenomena. Therefore, in this study, the CVA method was employed to assess desertification in Dehshir Plain, Yazd province, Iran.

According to Figure 5, the strength of changes was higher in the north, northeast, south, and southwest parts of the plain, which happened because of degradation and rehabilitation in the study area. This condition is consistent with changes in BSI and NDVI during two periods which is shown in Figure 4. According to Figure 4, the value of NDVI has increased in the southwest of the plain in the second period compared to the first period while the value of BSI has declined in this part in the second period compared to the first period. This result illustrated the relationship between

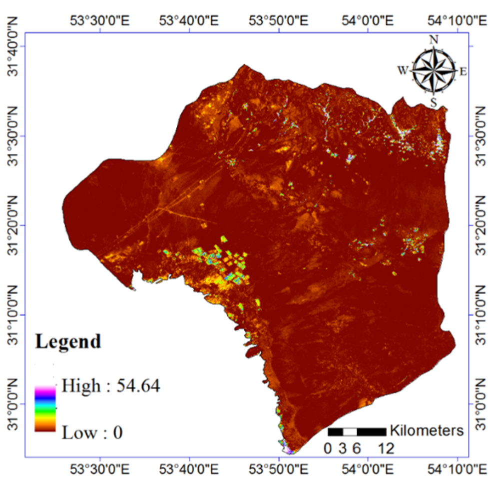

Figure 5. The strength of changes.

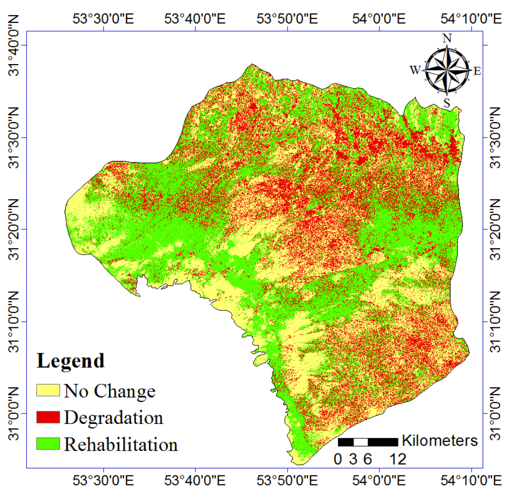

Figure 6. The direction of changes.

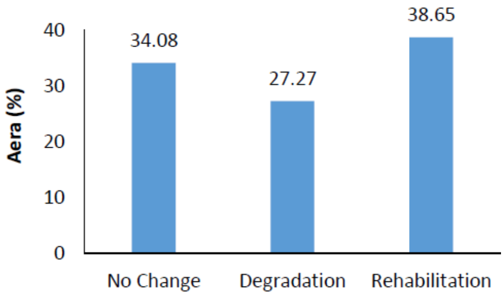

Figure 7. The area percentage of different conditions.

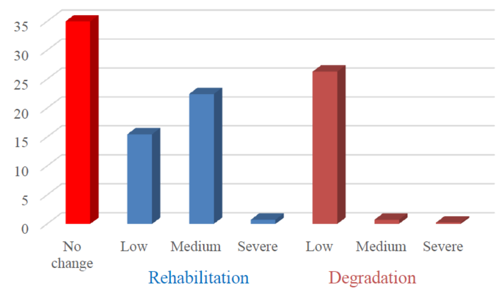

Figure 9. The area percentage of different classes.

these two indices and described that with an increase in vegetation cover (rehabilitation), the bare soil index showed a decline (desertification). This finding is consistent with Alqasemi et al. (2021).

According to Figure 6, in the north, northeast, and southeast parts of the region, the direction of changes is degradation. Adversely, in the western and southwest parts of the plain, the direction of changes is rehabilitation. The increase in NDVI value toward these directions during two periods also confirmed this result. This finding is in line with Behrang Manesh et al. (2020), who showed an increase in NDVI has caused a decrease in degradation.

The severe and medium intensity classes of degradation were related to the northern and northeast parts of the region. These parts are mainly around the drainage networks, the margin of rivers, and big villages with agricultural land use that have been influenced by excessive droughts in recent years and faced the destruction of vegetation cover and increase of desertification. In other words, climate fluctuation, drop in rainfall, and successive droughts in recent years have led to the destruction of vegetation cover, the drying up of rivers, and the reduction of local communities' desire to farm.

The intensity of rehabilitation was medium in the north, northeast, northwest, and east of the region, and it has increased significantly in the west. The site with a high class of rehabilitation includes Pistachio planting lands which have been increasingly common in recent years. In this context, the change vector analysis method showed the changes well. The results of Becerril-Pina et al. (2016) also confirm the good efficiency of the method. Also, the low and medium classes of rehabilitation are related to the rangelands. This area was under the pressure of large numbers of livestock. Amani et al. (2018) have also attributed the degradation of the Bijar protected area's rangelands to animals' presence.

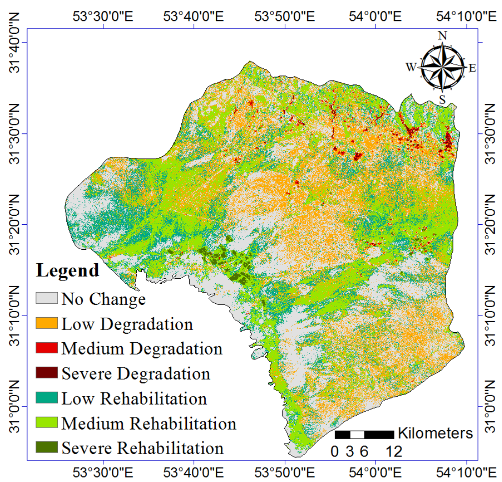

Figure 8. The different intensities of rehabilitation and degradation in the region.

Conclusion

The desertification phenomenon is one of the most prominent aspects of natural resource degradation globally, and many global efforts have been made to combat it for a few decades. Providing management solutions for combating desertification requires monitoring and assessing the severity of this phenomenon. In this research, the Dehshir Plain's desertification in Yazd province was evaluated and monitored using the change vector analysis method. According to the results, the change vector analysis method was able to show the intensity of degradation in the study area. However, it's suggested that the change vector analysis method be used in different regions using different soil and vegetation indicators to better judge this method's efficiency.

Acknowledgment

This chapter forms part of Esmaeil Heydari Alamdarloo's postdoctoral project (Number: 99017799) with the title of Feasibility Study of Proposing an Early Warning System for Desertification of IRAN using Remote Sensing Data. The Iran National Science Foundation (INS) is thanked for its financial support.

Authors contributions
All authors have contributed equally to prepare the paper.

Availability of data and materials
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Open access

References

Abolhasani A., Zehtabian Gh.R., Khosravi H., Rahmati O., Heydari Alamdarloo E., D' odorico P. (2022) A new conceptual framework for spatial predictive modelling of land degradation in a semiarid area. *Land degradation and development* 33 (17): 3358–3374.

Allen T.R., Kupfer J.A. (2000) Application of spherical statistics to change vector analysis of landsat data: southern aalachian spruce-fir forests. *Remote Sensing of Environment* 74 (3): 482–493.

Alqasemi A.S., Ibrahim M., Fadhil Al-Quraishi A.M., Saibi H., Al-Fugara A.K., Kaplan G. (2021) Detection and modeling of soil salinity variations in arid lands using remote sensing data. *Open Geosciences* 13 (1): 443–453.

Amani s., Joneidi H., Karami P. (2018) Assessing the effect of grazing intensity on vegetation changes in rangelands of bijar protected area. *The seventh National Conference of Rangeland and Range Management. Scientific-applied center of natural resources training of Dr Javanshir, Alborz province, Iran. (In Persian).*

Amiraslani F., Dragovich D (2011) Combating desertification in Iran over the last 50 years: an overview of changing approaches. *Journal of Environmental Management* 92 (1): 1–13.

Amiraslani F., Dragovich D., Caiserman A. (2018) A long-term cost-benefit analysis of national anti-desertification plans in Iran. *Journal of Desert* 23 (1): 141–151.

Bakhshandeh Mehr L., Soltani A. S.and Sepehr (2014) Assessing the current state of desertification and modifying MEDALUS model in segzi plain of Isfahan. *Journal of Range and Watershed Management* 66 (1): 27–41. (In Persian)

Becerril-Pina R., Díaz-Delgado C., Mastachi-Loza C. A., González-Sosa E. (2016) Integration of remote sensing techniques for monitoring desertification in mexico. *Human and Ecological Risk Assessment: An International Journal* 22 (6): 1323–1340.

Behrang Manesh M., Khosravi H., Azarnivand H., Senator A. (2020) Quantifying the trend of vegetation changes using remote sensing (case study: fars province) *Journal of Plant Ecosystem Conservation* 7 (15): 295–318. (In Persian)

Davari S., Rashki A., Akbari M., Talebanfard A. (2017) Assessing intensity and risk of desertification and management programs (case study: ghasemabad plain of bajestan, khorasan razavi province). *Journal of Desert Management* 5 (9): 91–106. (In Persian)

Dawelbait M., F. Morari (2012) Monitoring desertification in a savannah region in sudan using landsat images and spectral mixture analysis. *Journal of Arid Environ* 80:45–55.

Eastman J.R. (2015) TerrSet manual. *Accessed in TerrSet version* 18:1–390. clarklabs.org

Fitrianto A. C., Darmawan A., Tokimatsu K., Sufwandika M. (2018) Estimating the age of oil palm trees using remote sensing technique. *IOP Conference Series: Earth and Environmental Science.* 148 (1): 12020.

Hakimzadeh Ardakani M.A., Cheshmberah F., Mokhtari M.H. (2017) Investigating the effects of land use changes on trend of desertification using remote sensing (case study: abarkooh plain, Yazd, Iran). *Journal of Rangeland Science* 7 (4): 348–360.

Heydari Alamdarloo E., Behrang Manesh M., Khosravi H. (2018) Probability assessment of vegetation vulnerability to drought based on remote sensing data. *Environmental Monitoring Assessment* 190 (12): 1–11.

Karnieli A., Qin Z., Wu B., Panov N., Yan F. (2014) Spatio-temporal dynamics of land-use and land-cover in the mu us sandy land, China, using the change vector analysis technique. *Remote Sensing* 6 (10): 9316–9339.

Khiry M.A., Csaplovic E., Mahmoud T.E. (2015) Change vector analysis for analyzing and mapping desertification processes in arid and semi-arid region, north kordofan state, sudan. *American Association for Science and Technology* 2 (6): 301–306.

Khosravi H., Haydari E., S. Shekoohizadegan., S. Zareie. (2017) Assessment the effect of drought on vegetation in desert area using landsat data. *The Egyptian Journal of Remote Sensing and Space Science* 20 (1): s3–s12.

Lamchin M., Lee J.Y., Lee W.K., Lee E.J., Kim M., Lim C.H., Choi H.A., Kim S.R. (2016) Assessment of land cover change and desertification using remote sensing technology in a local region of mongolia. *Advances in Space Research* 57 (1): 64–77.

Lorena R.B., Santos J.R., Shimabukuro Y.E., Brown F. (2002) A change vector analysis technique to monitor land use/land cover in SW brazilian amazon: acre state. *PECORA 15-Integrating Remote Sensing at the Global, Regional and Local Scale,* 8–15.

Marinică I., Marinică A. F. (2014) Consideration on desertification phenomenon in Oltenia. *In Forum Geographic* 13 (2): 136–147.

Rafiei Sardooi E., Azareh A., Eskandari Damaneh H., Skandari Damaneh H. (2021) Drought monitoring using MODIS land surface temperature and normalized difference vegetation index products in semi-arid areas of Iran. *Journal of Rangeland Science* 11 (4): 402–418.

Rahimi M., Damavandi A.A., Jafarian V. (2013) Studying remote sensing applications in assessing and monitoring land degradation and desertification. *Scientific Research Quarterly of Geographical data (SEPEHR)* 22 (88): 115–128. (In Persian)

Rikimaru A., Roy PS., Miyatake S. (2002) Tropical forest cover density mapping. *Tropical Ecology* 43 (1): 39–47.

Sadeghiravesh M.H., Khosravi H., Abolhasani A., Ghodsi M., Mosavi A. (2021) Fazzy logic model to assess desertification intensity based on vulnerability indices. *Acta Polytechnica Hungarica* 18 (3): 7–24.

Sadeghiravesh M.H., Zehtabian Gh.R., Khosravi H. (2014) Application of AHP and ELECTRE models for assessment of desertification alternatives. *Journal of Desert* 19 (2): 141–153.

Shao Q., Shi Y., Xiang Z., Shao H., Xian W., Peng P., Li Q. (2018) Monitoring the grassland change in the qinghai-tibetan plateau: a case study on Aba county. *Journal of the Indian Society of Remote Sensing* 46 (4): 569–580.

Silakhori E. (2014) Mapping of desertification hazard intensity based on soil index using ESAs methodology in mazinan of sabzevar. *Journal of Emergency Management* 3 (2): 57–63. (In Persian)

UNCCD (2012) United Nations Convention to Combat Desertification in Bonn, Germany. https://doi.org/https://www.unccd.int/

Vali A.A., Mousavi S.H., Sadat Ahmadi S.M. (2015) Assessment of desertification intensity in masjed soleiman basin using IMDPA model. *Journal of Desert Ecosystem Engineering* 4 (9): 43–56. (In Persian)

Vorovencii I. (2017) Applying the change vector analysis technique to assess the desertification risk in the southwest of romania in the period 1984–2011. *Environmental monitoring and assessment* 189 (10): 1–8.

Xiao J., Shen Y., Tateishi R., Bayaer W. (2006) Development of topsoil grain size index for monitoring desertification in arid land using remote sensing. *International Journal of Remote Sensing* 27 (12): 2411–22.

Zaady E., Karnieli A., Shachak M. (2007) Applying a field spectroscopy technique for assessing successional trends of biological soil crusts in a semi-arid environment. *Journal of Arid Environments* 70 (3): 463–477.