Evaluating and Modeling Temporal-Spatial Changes of Land Use in the Expansion of Desertification Intensity in the Arid Regions of Northeast Iran (Sarakhs)

Mahboobeh Sarbazi [a], Majid Ownegh [b*], Ali Mohammadian Behbahani [c], Morteza Akbari [d]

[a] *PhD Candidate in combat desertification, Gorgan University of Agriculture Sciences and Natural Resources*
[b] *Professor inGeomorphology, Department of Range Land and Watershed Management of Gorgan University of Agriculture Sciences and Natural Resources, Gorgan, Iran*
[c] *Assistant Professor, Wind Erosion Modelling, Department of Range Land and Watershed Management, Gorgan University of Agriculture Sciences and Natural Resources, Gorgan, Iran*
[d] *Assistant Professor, Desertification risk monitoring, Department of Desert Area Management, Faculty of Natural Resources and Environment, Ferdowsi University of Mashhad, Mashhad, Iran*

Received: 6 March 2020
Accepted:12 September 2020

1. Introduction

Increasing land-use changes have increased the need for managers and experts in land resources to understand how changes and developments have occurred as well as possible future changes for good and efficient policymaking and decision-making (Parker et al., 2003; Akbari et al., 2019). Today, land use change is important in terms of environmental change and has got the attention of scientists and decision makers (Mas et al., 2014).

The increasing destruction of natural resources in many parts of the world is a serious threat to humanity. Therefore, desertification, which is one of the manifestations of this destruction, is currently a problem in many countries, including developing countries (Parvaneh, 2009). At present, remote sensing technology with the highest speed and accuracy is a suitable tool for assessing land use changes in order to monitor desertification (Hashemi-Nasab et al., 2018; Davari et al., 2018). Different land use models have been designed and used by researchers to predict land use changes in several studies such asDavolbit and Morari (2012) in Sudan, Lamchin et al. (2016) in Mongolia, Halabian et al. (2016) in Iran, Isfahan, using land use modeling, assessing and predicting desertification changes.

Studies show that in recent years, land cover around the world has undergone many changes that can severely affect the environment and natural resources. Given that land degradation leads to desertification, this issue intensifies the importance of studying land cover changes, considering the strategic importance of Sarakhs region. In the present study, the temporal-spatial changes of land use in intensity of desertification have been investigated and modeled using satellite images.

[*]. Corresponding author: Majid Ownegh. E-mail:ownegh@gau.ac.ir Tel: +9801732427173

2. Study Area

The study area of Sarakhs is a small part of the great Gharakhum basin which is located in Sarakhs city. The border of the region is in the western and southwestern part of Bazangan and Shurluq mountains, in the northern part is the Iran-Turkmenistan political border and in the eastern part of Tajan river. Geographically, the ferns range is located at 60 degrees 15 minutes to 61 degrees 10 minutes east longitude and 35 degrees 50 minutes 36 degrees 40 minutes north latitude. This area is naturally prone to desert expansion, which is exacerbated by its proximity to the Qaraqoom desert, creating a dry and cold climate. Wind erosion is more common in arid climates, where soil productivity intensifies drying conditions. Sarakhs region suffers from critical desertification conditions due to arid climate, low rainfall, unfavorable soil, land use change and increased wind erosion. The study area, as the epicenter of wind erosion crisis, has created environmental problems. Therefore, due to acute environmental and human problems and strategic location, Sarakhs was selected as the study area.

3. Materials and Methods

In this study, Landsat TM and ETM+ sensors were used to study land use dynamics. Geometric, radiometric and atmospheric corrections were performed on the images. Satellite imagery from 2000 to 2015 was monitored to prepare the land use map and examine its changes over 15 years. In this study, Landsat satellite imagery classification maps were first prepared using the maximum likelihood method for the mentioned years. Finally, the user map for different years was prepared. The LCM Land Change Modeler was used to model land use change in 2030. Modeling in this model was done in three stages. In the first stage the influential variables were selected and introduced to the model and the role of each of them according to the Kramer coefficients was determined. In the second stage, the potential transfer map was prepared based on the effective variables and land use maps of the previous periods and in the third stage, the future land use map was prepared. The validity and reliability of the modeling and classification maps are based on the estimation of the kappa coefficient and overall accuracy. Common validation maps of classification lands and changes model prediction maps were used for validation. In this way, the predicted map of the model was compared with the land use map produced by the supervised method and obtained by calculating the standard kappa coefficient, position accuracy status and pixel quantities of each class.

4. Results and Discussion

Map of land use classes of Sarakhs area in six classes of water level, agricultural lands, poor, and bay rangelands, medium and rich rangelands, wind deposits and residential areas and Landsat satellite imagery classification for the years under study were prepared. To determine the percentages of land use changes in the study period, each of the classes obtained in different years was individually placed on the sum of the classes obtained the following year, and then the number of changes of each of these uses was calculated in 2015. To import the variables into the land change modeler, it is necessary to map the variables. Altitude variables, distance from residential areas, distance from the road, distance from river and distance from agricultural land were selected as input variables of the model. It is possible to estimate the correlation of each variable with the existing land use and its ability to predict land use changes by calculating the Kramer coefficient. After revealing land use changes over the years 2000 to 2015, the number of changes in each transfer was predicted using the Markov Chain and the total land-use change map in the LCM model for 2030. To validate the power of the LCM model to produce land use maps for 2030, the 2000 and 2005 maps were first used to predict the 2015 map. To make this prediction, the change probability matrix and the probability area matrix of changes were prepared and based on defined sub-models and change probability maps, the 2015 land use map was prepared. Comparison of the model predicted map with the land use map prepared by the supervised method and calculation of standard kappa coefficient, accuracy condition for position and quantity of pixels of each class were obtained. The 2015 ground truth map was then compared with the simulated map of the land-change modeler. The accuracy of the model was evaluated based on the Kappa index. The error matrix results showed that the kappa coefficient of variation in the land change model is 0.85. Using the multilayer Preston neural network approach, the user change map for 2030 was obtained. According to the results, the process of reducing the average and rich rangelands and agricultural lands continues. The extent of wind deposits will also increase, covering about 17% of the area in 2030.

5. Conclusion

In the present study, land use changes in the north east of the country over the three-time periods 2005 to 2015 were investigated using Landsat satellite imagery and the ability to predict land-use changes based on the LCM modeling approach. Comparative results of land use maps in the three mentioned periods show the level of change in all land uses. The degradation of medium and rich rangelands in the third period was higher than the degradation of the second and first periods, indicating more severe degradation in the 2015–2010 period. One of the reasons for most of the degradation of rich rangeland during this period is the reduction of rainfall, drought and surplus livestock in recent years. The most varied land use changes over the years can be attributed to a decrease of about 3 percent in medium and rich rangelands, an increase of three percent in poor and barren rangelands and an increase of about one percent in agricultural lands. The total area of the sand has increased by more than 1% over the whole period. The decrease in rangeland and the increase in waste and agricultural land indicate the inappropriate use of these lands for agricultural purposes. Damage to rangelands, increased levels of agricultural land with the degradation of land, use of land outside their ability and potential have led to increased desertification. During this period, the area of residential areas grew by about 0.2%. The results of predicting changes over the next 11 years using the LCM modeler show that if the current trend continues in the region, the development of sand dunes and increased rangeland destruction will continue. In the 2030 horizon, sandy zones will cover about 17 percent of the area, and the extent of the desert and poor rangelands will be about 60 percent.

Keywords: Predicting Land Use Changes, Satellite Images, Desertification, LCM Modeler, Desertification

References: (In Persian)

Akbari, M. (2016). *ارائه سیستم پیش‌آگاهی خطر بیابان‌زایی (منطقه مورد مطالعه: مناطق نیمه بیابانی غرب استان گلستان)* [Proposing an early warning system for desertification hazard (Case study: Semi desert region of the Gorgan Plain, Golestan Province)], (Unpublished doctoral dissertation). Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran.

Ashuri, H. (2015). *پایش تغییرات زمانی و مکانی کاربری اراضی مرتعی حوضه آبخیز سیدان با استفاده از داده‌های سنجش از دور.* [Monitoring temporal and spatial land use changes of Seydan watershed using remote sensing data], (Unpublished master's thesis). Ferdowsi University of Mashhad, Mashhad, Iran.

Davari, S., Rashaki, A., Akbari, M., & Talebanfard, A. A. (2019). پایش تغییرات زمانی- مکانی شاخص‌های مؤثر بیابان‌زایی مناطق خشک جنوب خراسان رضوی. [Monitoring of spatio-temporal variations of effective desertification indices in arid regions of south Khorasan Razavi]. *Journal of Remote Sensing and Geographic Information Systems in Natural Resources, 31*(2), 17-32

Fathollahi Rudbari, S. M., Khanmohammdi, M., & Nasirahmadi, K. (2018). مدل‌سازی تغییرات کاربری اراضی با استفاده از مدل‌ساز تغییر سرزمین مطالعه موردی: شهرستان نکا. [Modeling land use change using land change modeling (LCM); Case study: Neka County]. *Iranian Journal of Natural Ecosystems, 9*(1), 53-69.

Halabian, A. H., & Soltanian, M. (2016). *ارزیابی و پیش بینی تغییرات بیابان زایی در شرق و جنوب اصفهان با مدل* CA-Markov. [Evaluation and prediction of desertification changes in the east and south of Isfahan with CA-Markov model]. *Journal of Spatial Analysis of Environmental Hazards. 3*(4), 71-88

Hasheminasab, S. N., & Jafari, R. (1977). ارزیابی تغییرات کاربری اراضی به منظور پایش بیابان‌زایی [Evaluation of land-use changes for desertification monitoring]. *Journal of Spatial Analysis of Environmental Hazards, 5*(3), 59-74.

Majdab Shargh Consulting Engineers. (2014). *طرح الگوی مشارکت جوامع محلی و دستگاه‌های اجرائی در احیاء منابع طبیعی شهرستان سرخس.* [Drafting the pattern of participation of local communities and executive bodies in the restoration of natural resources in Sarakhs]. Tehran, Iran: Majdab Shargh Consulting Engineers.

Mohammad Esmaeil, Z. (2010). پایش تغییرات کاربری اراضی کرج با استفاده از تکنیک سنجش از دور [Monitoring Karaj land use changes using remote sensing technique]. *Journal of Soil Research (Soil and Water Sciences), 24*(1), 81-88.

Nazari Samani, A. A., Ghorbani, M., & Kouhbanani, H. R. (2010). ارزیابی روند تغییرات کاربری اراضی حوضۀ آبخیز طالقان در دورۀ ۱۳٦٦ تا ۱۳۸۰. [Evaluation of land use changes in Taleghan Watershed from 1366 to 1380]. *Rangeland Scientific Journal, 4*(3), 451-442.

Parvaneh, H. (2009). *ارزیابی وضعیت فعلی بیابان‌زایی در خراسان جنوبی با استفاده از روش مدالوس- منطقه طبس مسینا- شهرستان درمیان.* [Evaluation of the current situation of desertification in South Khorasan using Madalus method - Tabas region, Messina - Darmian city], (Unpublished master’s thesis). University of Isfahan, Isfahan, Iran.

Vafaiee, S. (2013). *پایش و پیش‌بینی تغییرات کاربری اراضی با استفاده از سنجش از دور و GIS (منطقه مـورد مطالعـه: منطقه مریـوان).* [Assaying and predicting the land uses changes using remote sensing and GIS (The studied area: Marivan], (Unpublished master’s thesis). University of Tehran, Tehran, Iran.

References: (In English)

Akbari, M., Nematollahi, E., & Nematollahi, P. (2019). Evaluating land suitability for spatial planning in arid regions of eastern Iran using fuzzy logic and multi-criteria analysis. *Ecological Indicators, 12*(98), 587-598.

Arzani, H., Mirakhorlou, K. H., & Hosseini, S. Z. (2009). Land use mapping using Landsat7 ETM data (Case study in middle catchment’s of Taleghan). *Iranian Journal of Range and Desert Research, 16*(2), 150-160.

Benediktsson, J. A., & Sveinsson, J. R. (1997). Feature extraction for multisource data classification with artificial neural networks. *International Journal of Remote Sensing, 18*(4), 727-740.

Bolstad, P. V., & Lillesand, T. M. (1991). Rapid maximum likelihood classification. *Photogrammetric Engineering and Remote Sensing, 57*(1), 67-74.

Chasek, P., Safriel, U., Shikongo, S. V., & Futran F. (2015). Operationalizing zero net land degradation: The next stage in international efforts to combat desertification. *Journal of Arid Environments*, *112*(1), 5 -13.

Coppin, P., Jonckheere, I., Nackaerts, K., Muys, B., & Lambin, E. (2004). Digital change detection methods in ecosystem monitoring: A review. *International Journal of Remote Sensing, 25*(9), 1565-1596.

Dawelbait, M., & Morari, F. (2012). Monitoring desertification in a Savannah region in Sudan using Landsat images and spectral mixture analysis. *Journal of Arid Environments, 80*(14), 45-55.

Du, Y., Teillet, P. M., & Cihlar, J. (2002). Radiometric normalization of multitemporal high resolution satellite images with quality control for land cover change detection. *Remote Sensing of Environment*, *82*(1), 123–134.

Eastman, J. R., Van Fossen, M. E., & Solarzano, L. A. (2012). *Transition potential modeling for land cover change In Maguire GIS. Spatial Analysis and Modeling*. Redlands, California: ESRI Press.

Fatemi, S. B., & Rezaei, Y. (2012). *Basics of remote sensing*. Tehran, Iran: Azadeh.

Gholamalifard, M., Jorabianshoshtari, Sh., Hosseini, S. H., & Mirzaei, M. (2012). Modeling land use change in the coast of Mazandaran province using LCM in GIS environment. *Journal of Ecology, 38*(64), 109-124.

Grainger, A. (2015). Is land degradation neutrality feasible in dry areas. *Journal of Arid Environments, 112*(14), 14-24.

Heidarian, P., Rangzan, K., Maleki, S., Taghizadeh, A. (2014). Integration of GIS and LCM measurement techniques with urban development modeling approach (Case study: Tehran Metropolis). *Journal of Arid environment research, 5(*17), 87-100.

Imeson, A. (2012). Desertification, land degradation and sustainability. New York, NY: Blackwell.

Jafari, M., ZehtaXbian, G. H., & Ehsani, A. H. (2011). Effect of thermal bonding and supervised classification algorithms of satellite data in making land use maps (Case study: Kashan). *Iranian Journal of Range and Desert Research*, 20(3), 72-87.

Kamyab, H., Mahini, S., Hosseini, A., & Gholamalifard, M. (2011). Application of artificial neural network in urban development modeling (Case study: Gorgan City). *Human Geography Research, 43*(76), 99-113.

Kavzoglu, T., & Mather, P. M. (2000). Using feature selection techniques to produce smaller neural networks with better generalization capabilities. *Geoscience and Remote Sensing Symposium*, *7*(2), 3069–3071.

Lambin, E. F. (1997). Modelling and monitoring land-cover change processes in tropical regions. *Progress in Physical Geography*, *21*(3), 375–393.

Lamchin, M., Lee, J., Lee, W., Lee, E., Kim, M., Lim, C., Choi, H. & Kim, S. (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.

Li, J., Yang, X., Jin, Y., Yang, Z., Huang, W., Zhao, L., Gao, T.,… Xu, B. (2013). Monitoring and analysis of grassland desertification dynamics using landsat images in Ningxia China. *Remote Sensing of Environment, 138*(34), 19-26.

Li, X., & Yeh, G. (2002). Neural-network-based cellular automata for simulating multiple land use changes using GIS. *Geographical Information Science,* 16(4), 323–343.

Mas, J., Kolb, F., Paegelow, M., Camacho Olmedo, M., & Houet, T. (2014). Inductive pattern-based land use/cover change models: a comparison of four software packages. *Journal of Environmental Modelling and Software*, *51*(13), 94-111.

Mas, J., Puig, H., Palacio, J., Sosa, L., & Lopel, A. (2004). Modeling deforestation using GIS and artificial neural networks. *Environmental Modeling and Software, 19*(5), 461-471.

Nedjai, R., Nghiem, V. T., Do, T. P. T., & Nasredine, M. N. (2016). The impact of land use and climate change in the center region of France on the physico-chemical status of aquatic systems. *International Journal of Spatial, Temporal and Multimedia Information Systems,* 1(1), 102-117.

Nkonya, E., & Anderson, W. (2014). Exploiting provisions of land economic productivity without degrading its natural capital. *Journal of Arid Environments, 112*(14), 33-43.

Olokeogun, O., Iyiola, K., & Iyiola, O. (2014). Application of remote sensing and GIS in land use/land cover mapping and change detection in Shasha forest reserve, Nigerqia. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science*, *8*(1) 613-616.

Parker, D. C., Manson, S., Hoffmann, M., & Deadman, M. J. (2003). Multi agent systems for the simulation of land use and land cover change. a review. *Annals of the association of american geographers. 93*(2), 314–337.

Saifullah, K., Barus, B., & Rustiadi, E. (2017). Spatial modelling of land use/cover change (LUCC) in South Tangerang City, Banten. In IOP Conference Series: Earth and Environmental Science, Volume 54, conference 1.

Stavi, I., & Rattan, L. (2015). Achieving Zero Net Land Degradation: Challenges and opportunities. *Journal of Arid Environments, 112*(14), 44-51.

Stéphenne, N., & Lambin, E. F. (2001). A dynamic simulation model of land-use changes in Sudano-sahelian countries of Africa (SALU). *Agriculture, Ecosystems and Environment, 85*(1-3), 145–161.

Tal, A. (2015). The implications of environmental trading mechanisms on a future Zero Net Land Degradation protocol. *Journal of Arid Environments, 112*(14), 25-32.

Yuan, F., Sawaya, K. E., Loeffelholz, B. C., & Bauer, M. E. (2005). Land cover classification and change analysis of the Twin Cities (Minnesota) Metropolitan area by multi temporal Land sat remote sensing. *Remote Sensing of Environment, 98*(2-3), 317-328.