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SPATIO-TEMPORAL DYNAMIC OF LAND DEGRADATION USING REMOTE SENSING-BASED INDEX

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ABSTRACT

Land degradation is the major issue which affect watershed sustainability and following social, economic and environmental of livelihood people. So, early detection of land degradation is necessary for policy-makers to make appropriate decision. In this way, remote sensing method is a candidate choice for assessments and monitoring. In this study, land degradation was assessed using Rain-Use Efficiency (RUE) in the Shazand Watershed, Iran in 1986, 1998, 2008 and 2016. Thus, annual rainfall was calculated using inverse distance weight (IDW), net primary productivity (NPP) were calculated using Landsat images. The results indicated that RUE had increasing and then decreasing trends which were 10.66, 33.77, 20.03 and 9.47 kg C ha^{-1} yr^{-1}. The results also illustrate that the mean value of RUE in different land uses varied between the irrigated land and orchard that had the highest value and outcrop dominant areas and bareland had the lowest value of RUE among land use categories. It is also established that spatio-temporal analysis of RUE can provide valuable information about the trend of watershed's sustainability over years.

Key Words: *Land use/cover, Watershed Sustainability, Watershed Health, Watershed Management.*

INTRODUCTION

Land degradation (LD) is one of the most serious environmental and socio-economic problems (Wang et al., 2014) due to which more than 250 million people are directly influenced. The UNCCD, the Convention on Biodiversity, the Kyoto Protocol on global climate change, and the Millennium Development Goals have highlighted land degradation as a development challenge (Yengoh et al., 2015). So, identification, rehabilitation and applying preventative measurements are necessary for LD assessment to efficiently mitigate LD-related issues. Vegetation cover is a good indicator for LD. Different researchers have used various vegetation-based indices to analyze LD in global, national, local and field levels (Wang et al., 2014). Among different vegetation-based indices, the

Normalized Difference Vegetation Index (NDVI) is one of the most effective indicator for monitoring watershed health, watershed sustainability and LD (Li et al., 2015). By considering that climatic conditions affect NDVI, so exploring the relationship between NDVI and precipitation is a helpful manner to mirror LD. Accordingly, Rain Use Efficiency (RUE) which is defined as the ratio between Net Primary Production (NPP) and rainfall (Vermeire et al., 2009), is a useful indicator for land degradation and vegetation cover (Fensholt et al., 2013) reflecting the ecosystem functioning and structure.

RUE in unhealthy watersheds are more than that of degraded one with the similar rainfall. It is due to more runoff generation and less biomass production in degraded watersheds (Wessels et al., 2007). There is a strong relation between rainfall and RUE in that increasing and decreasing of RUE may be in the result of rainfall increasing and decreasing. However, this positive relation doesn't exist in all region because RUE is controlled by several factors such as vegetation composition, soil condition and biogeochemical constraints (Bhandari et al., 2015). Hence, spatial pattern of RUE and effective factors are different from site to site (Jia et al., 2015). RUE is an appealing concept which is calculated by both remote sensing and ecological interpretation (Dardel et al., 2014; Huang and Xu, 2016; Liu et al., 2018). Many researchers consider Satellite images as an ideal technology for LD (Vermeire et al., 2009; Dan et al., 2018; Kundu et al., 2018). It provides conditions to analyze timely and high temporal frequencies in large areas (Wang et al., 2014). In this way, many researches have calculated NPP using vegetation indices particularly NDVI.

The present study has tried to investigate LD by analyzing the spatial and temporal dynamic of RUE in different year of 1986, 1998, 2008 and 2016. Furthermore, its relation with rainfall and in various land uses/covers were also assessed.

MATERIAL AND METHOD

Study area

The Shanzand watershed is located in Markazi Province, Iran (49° 4' to 49° 52' E and 33° 44' to 34° 12' N) covering an area of 1,740 km^2. The climate of the watershed is moderate semi-arid to cold semi-arid. The elevation varies between 1800 to 3300 m which resulted in spatial and temporal distribution of rainfall. The mean annual rainfall is 420 mm the mean annual temperature is 12 °C (Hazbavi and Sadeghi, 2017). Farming was dominant in past decades. Whilst, land use change especially urban and industries development and orchard extension occurred after 1998 (Davudirad et al., 2016).

Land use classification

The land use maps of the Shazand watershed for 1986, 1998 and 2008 were extracted from existing researches (Davudirad et al., 2016) and for 2016 was developed using maximum likelihood method. Some eight land uses/ covers viz. bareland, dry farming, forest, irrigation farming, orchard, rangeland, residential and outcrops dominant areas were recognized.

RUE calculation

NPP and NDVI of MODIS products were downloaded for study area and their relationship was obtained. The monthly images of Landsat TM, ETM+ and OLI (1986, 1998, 2008 and 2016) were also collected. The necessary geo-referenced, radiometric and atmospheric corrections were performed and NDVI map was calculated to use for analyzing the relation between NDVI of Landsat and MODIS. Then NPP was calculated in 30 m using extracted equation. RUE was eventually calculated using following equations:

$$\mathrm{RUE} = \frac{\mathrm{NPP}}{\mathrm{P}} \qquad (1)$$

where P is annual rainfall and NPP is net primary production.

The rainfall datasets of eight stations in and around the watershed were received from the Markazi Meteorological Bureau and averaged with the help of Inverse Distance Weighted (IDW) technique in ArcGIS 10.4.1 environment.

RESULT AND DISCUSSION

Land use/cover maps

Based on methodology explained above, land uses/covers maps were developed for the study years as depicted in Fig. 1.

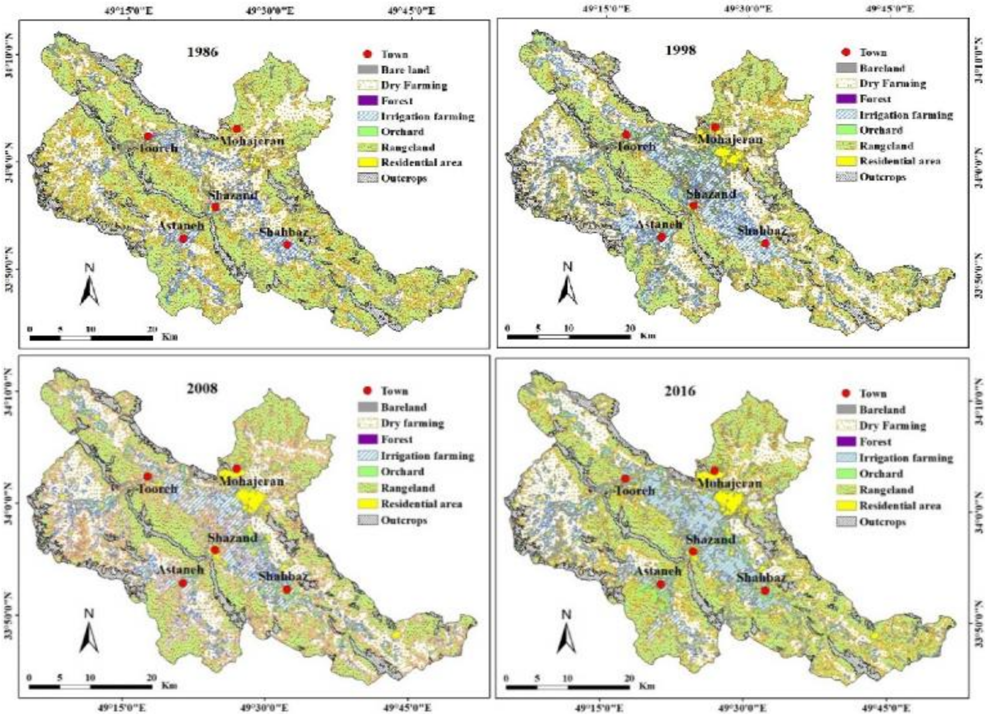

Figure 1. Land uses/covers maps for study node years in the Shazand Watershed, Iran

Spatial and temporal variation of RUE

The spatial distributions of RUE for study node years of 1986, 1998, 2008 and 2016 with mean values of 10.66, 33.77, 20.03 and 9.47 kg C ha^{-1} mm^{-1} have been mapped in Fig.2. Fig. 3 shows that RUE value had an increasing trend until 2008 and then it decreased to the lowest value in 2016. It means the watershed function tended to be degraded and the vegetation ability to use water decreased in 2016. High values of RUE in 1998 and 2008 indicate a better condition of RUE and more efficiency of rainfall to produce vegetative biomass.

Annual rainfall for 1986, 1998, 2008 and 2016 as respective amount of 455.93, 458.41, 311.31 and 479.71 mm verified a negative relationship with RUE. So that, dry years and years followed by dry years had the high value of RUE. Inversely, wet years had the low value of RUE. This implied that others biotic and abiotic factors affect RUE to get access to maximum level of efficiency. This results is consistent with Huang and Xu (2016), Liu and Huang (2016), and Sun and Du (2017) that indicated a negative correlation between RUE and rainfall. Furthermore, this result agreed with Zhang et al. (2014) who concluded that rainfall variations in current- and previous-year affected RUE. However, they found a dry year preceded by a wet year resulted in the highest RUE. The results also verified fragile condition of the study watershed in viewpoint of LD as already reported by Davudirad et al. (2016) and Hazbavi and Sadeghi (2017), and Sadeghi and Hazbavi (2017).

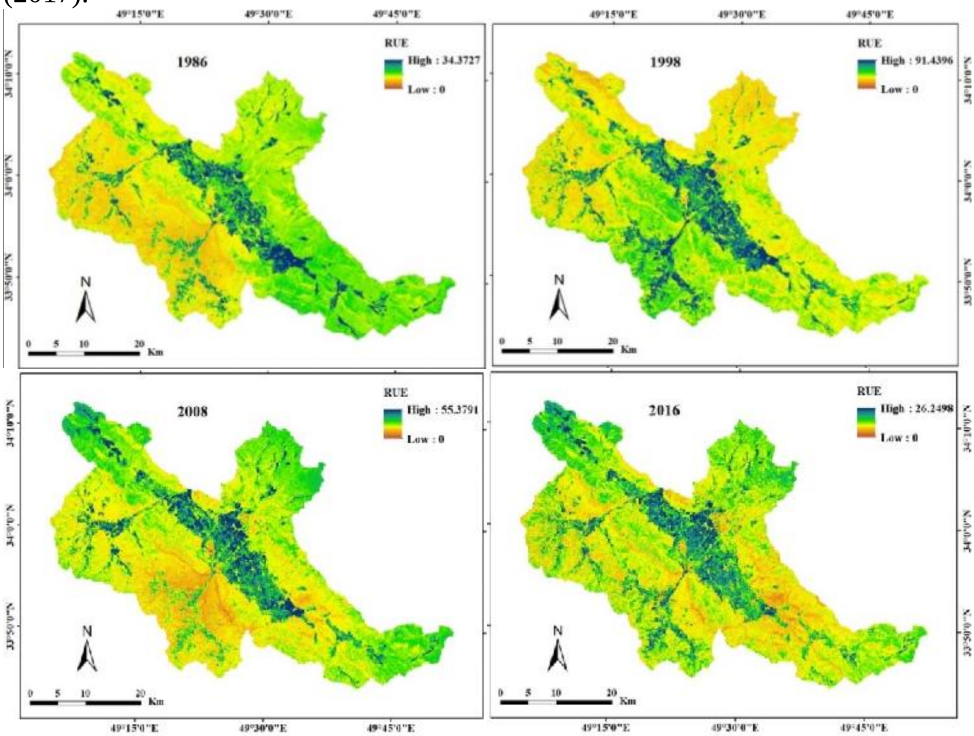

Figure 2. Spatial pattern of rain use efficiency (RUE) in study years in the Shazand Watershed, Iran

Relationship between RUE and land use/cover

The relationship between RUE and land use/cover was investigated in study years to examine land degradation condition. Table 1 illustrates the mean value of RUE in different land uses. It can be seen that the irrigation lands and orchards had the highest value and outcrops dominant areas and sparse forest had the lowest value of RUE among land use categories in study years.

Table 1. Rain use efficiencies in different and uses/covers from 1986 to 2016 in the Shazand Watershed, Iran

Node year	Rangeland	Dry farming	Irrigation farming	Orchard	Residential	Outcrops dominant areas	Bareland	Sparse Forest
1986	9.84	11.08	18.95	20.02	11.50	9.00	9.71	7.44
1998	30.95	31.13	51.72	48.23	31.93	28.21	29.15	32.42
2008	19.15	18.78	26.80	24.00	19.35	17.19	18.10	14.46
2016	8.96	9.02	12.54	10.85	9.11	8.12	8.40	8.69

CONCLUSION

Monitoring and evaluating the watershed health is vital for proper watershed management and implementation of revitalization measures leading to the functional sustainability of the system. Identification of land degradation in low intensity or early stages help policy makers take restorative or preventative actions before its damages became worse. In this study, the dynamics of RUE was examined in the Shazand Watershed in relation to rainfall and land use/cover. The results showed that RUE variations are not solely controlled by the rainfall of the year under consideration. Furthermore, mean value of RUE in different land uses/covers were different so the irrigation land and orchard had the highest value and outcrops dominant areas and bareland had the lowest value of RUE. The result provided an important platform in watershed monitoring and decision-making. However, the further studies with comprehensive factors are needed to minutely investigating RUE evolution.

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