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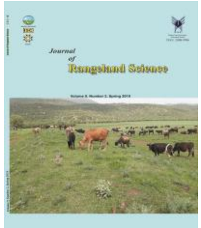

Research and Full Length Article:

Impact of Regional Rangeland Cover Degradation on Increasing Dusty Days in West of Iran

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Abstract. Dust events of Iran mainly originate from Iraq, Syria, Saudi Arabia, Kuwait and inland territories which are influenced by droughts and Land Use/Land Cover (LU/LC) degradation in regional scale. The aim of this research was to investigate the impact of Regional Vegetation Cover Degradation (RVCD), particularly Regional Rangeland Cover Degradation (RRCD) on frequency of dusty days in western provinces of Iran (Khorramabad, Ahvaz, Hamadan and Kermanshah) since 2000. Therefore, the LU/LC and RRCD were evaluated with respect to time-series MODIS satellite images and NDVI Index. The trend of RRCD was predicted by Markov chain analysis for 2030, 2060 and 2100. The accuracy analysis of comparing the observed and predicted LU/LC classes to 2000 and 2016 indicated the absolute value of error around 5.49%. The findings showed that probability of changing from water body, high-cover and low-cover classes to non-cover class would probably be 55% and 62% during 2016-2030 and 2030-2060, respectively. Durability of non-cover class was 89% during 2000-2016. Thus, the area of non-cover class increased to 410 km^2 in the study region. In general, it could be noted that increasing of RRCD and drought are the main causes of dusty days increasing from 2000 to 2060.

Key words: Degradation Trend, Rangeland Cover, Dusty Days, Markov Chain

Introduction

During the recent decades, climate change and mismanagement of natural resources and wetlands have caused Vegetation Cover Degradation (VCD) in Iran and its western neighboring countries such as Iraq, Turkey, Syria, Saudi Arabia and Kuwait. Sand and dust storms are known as hazardous problems in arid and semi-arid areas, which their frequencies and intensities have increased significantly in western Iran. Urban and rural areas, rangelands, farmlands and forests of west and south-west of Iran are directly affected by dusty weather coming from these countries. Dust particles would absorb and reflect radiation which influences energy balance, cloud formation and climate fluctuation or change (Choupani, 2009: Shao and Wong, 2003). Droughts and VCD are effective causes in frequency of dusty days (Gao and Liu, 2010; Elie *et al*., 2017). Land use changes are the most important dynamic process for biodiversity conservation, human activities improvement, and sustainable development in the future (Verburg *et al*., 2009; Kanianska *et al*., 2014; Verburg *et al*., 2011; Brink *et al*., 2014; Russell-Smith et al., 2003; Lo & Quattrochi, 2003; Fraser *et al*., 2005). Land Use-Land Cover (LU/LC) change causes geochemical cycle and water quality change (Powers, 2004; Schippers *et al*., 2004). Evaluation of VCD change trend using GIS and satellite images is a cheaper and easier technique for environment management rather than traditional methods (Abd El-Kawy *et al*., 2011; Bakr *et al*., 2010; Mendoza *et al*., 2011; Coppin and Bauer, 1996). The RRCD is one of the most important LU/LC changes leading to soil erosion and dust storm in arid and semi-arid regions. Iran lies on the global desertification and wind erosion belts (Gholamalifard *et al*., 2013); therefore, it is considered as an area susceptible to dust storms, which may have great effects on daily life, health, agriculture, and watershed management. The mineral dusts entering to Asia has had large impact on regional air quality, energy and hydrological cycles, and ecosystems (Zhao, 2012). It is necessary to identify the causes of dust events in source areas due to soil and vegetation cover degradation and assess the sever impact on human health (Mousavi-Bayegi and Batoul, 2012). Recent studies have used GIS, remote sensing techniques, and different satellite images in the world. Baugh and Groeneveld (2006) evaluated vegetation indices (VIs) using a Landsat TM dataset over San Luis Valley, Colorado, USA. The results showed that the NDVI index is effective for use in the study areas. Rouse *et al.* (1973) found that the cultivation of marginal areas and overgrazing of pastures have resulted in degradation of land. Accelerated wind erosion on sandy surfaces and water erosion on the shallow soils of piedmont areas are both common. A quarter of the whole area needs urgent attention for soil conservation. Remote sensing has long been recommended for its potential role to detect, map and monitor degradation problems with spatial and spectral resolution and for the detection of degraded and disturbed regions (Sabins, 1987, Sujatha *et al*., 2000, Xiao *et al*., 2006).

In this research, Land use/ Land Cover and vegetation cover change were studied in western neighboring countries and inland territories of Iran. Effects of RRCD on dusty days using remote sensing and GIS in Ahvaz, Hamadan, Khorramabad, Sanandaj and Kermanshah stations in west of Iran.

Materials and Methods

Study Area

Subject areas are Iraq, northwest of Saudi Arabia, north of Kuwait, east of Syria, south of Turkey and west of Iran (Fig.1). These areas are located between 37.65-50.05 E and 29.15-37.51 N which are considered as the main sources of dust in Iran (Zazuli *et al*., 2014). This area is located in arid and semi-arid belt in subtropical climate (Gholamalifard *et al*., 2013). War, mismanagement of natural resources, global warming, and climate changes have caused vegetation and wetland degradation and dust increase. Westerly winds bring the sand and dust to west of Iran due to soil erosion and drought (Miri, 2011). There are 24 main synoptic stations which record dust and climatic data during the long period. Ahvaz, Hamadan, Khorramabad and Kermanshah are the most important stations on the basis of the spatial and temporal variability of dust storms, their relationship with climatic factors, and their synoptic patterns of generator using PCA and K-means methods. All dust storms coming to western Iran are measured and recorded at least in one of these main synoptic stations (Ghaffari and Nouri, 2016). The geographical location of the study area is shown in Fig. 1.

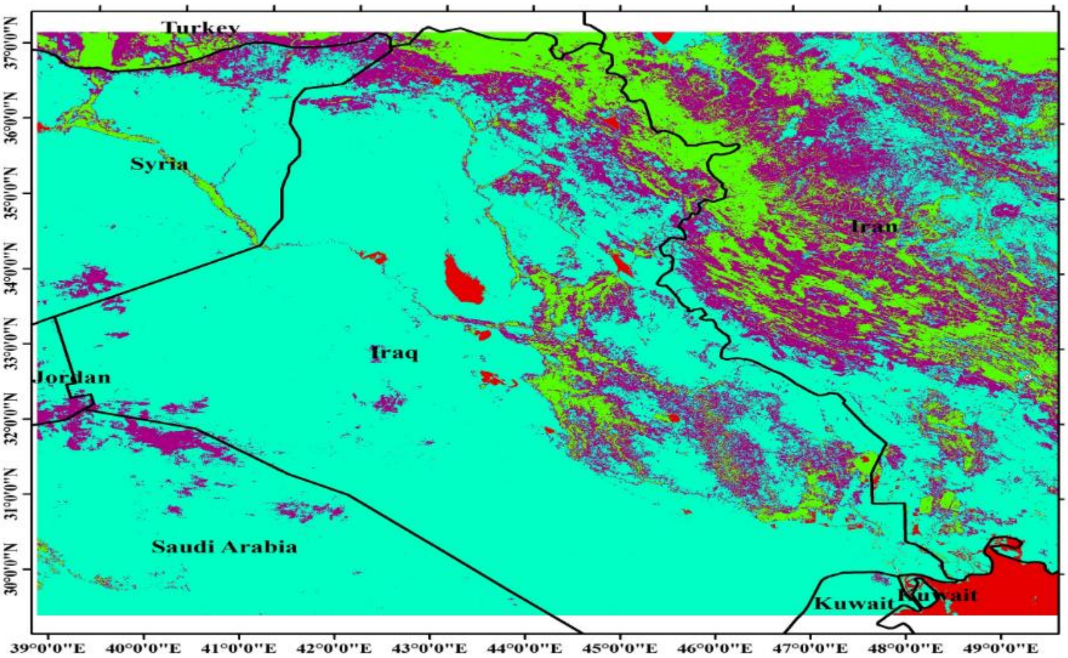

Fig.1. Location of study area in MODIS image

Methodology

In this research, the effects of RVCDT were studied on dusty days of a mountainous area over Zagros. The nine weather variables and dust synoptic codes (WW=06-09 and 30-35) are used to analyze climatology and present weather (WW) in four synoptic stations during 1982-2016. Detailed coding explanations for each class of the Synoptic code are given in WMO reports (Zazuli *et al*., 2014).

RVCDT of the subject area was studied using remote sensing, MODIS images and MARKOV analysis from 2000 to 2100. Schematic methodology is presented in Fig. 2.

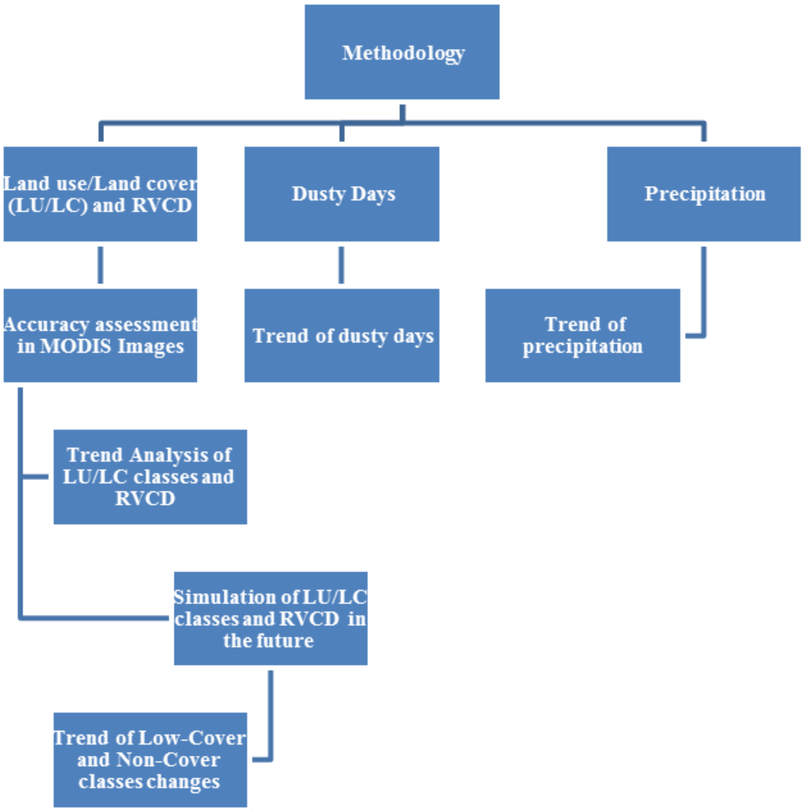

Fig. 2. Schematic Methodology in this research

Land use/land cover (LU/LC) maps

Vegetation indices were selected for LU/LC mapping because Vegetation cover degradation is the main reason for wind erosion and dust event in vulnerable regions (Asrar *et al*., 1984). Land use/land cover (LU/LC) maps were prepared using MODIS images and NDVI Index by the means of ENVI software. These maps were classified into four groups including water, non-cover, low cover and high cover, and their change trend was evaluated in the area (Huete, 1988; Rouse *et al*., 1973; Fensholt *et al*., 2009; Gu *et al*., 2007; Ghorbani *et al*., 2012) in 2000, 2012 and 2016 (Table.1).

Table 1. characteristics of satellite images

MODIS Product	Year	Julian day	Band number
MOD02QKM	2000	203	2
MOD02QKM	2012	204	2
MOD02QKM	2016	203	2

Accuracy

Accuracy of the classified maps was evaluated using error matric (Congalton, 1991; Foody, 2002). Kappa index and overall accuracy parameter were used for accuracy determination of the maps (Yuan *et al*., 2005). Also, different LU/LC classes were assessed by comparing the observed and simulated maps in 2016.

LU/LC change

Different classes' areas of LU/LC maps were computed and compared using GIS techniques in 2000, 2012 and 2016 (Hall *et al*., 1995).

Transition probability matrix

Transition probability matrix shows transition power from a land cover vegetation class to another (Elie *et al*., 2017; Merten and Lambin, 1997'; Linkie, *et al*., 2004; Schulz *et al*., 2010; Gholamalifard *et al*., 2013). Future changes for land cover vegetation classes were simulated using this matrix in 2000-2012, 2000-2016, 2000-2030 and 2000-2060 (Elie *et al*., 2017).

Trend Analysis and simulation of LU/LC in future

LU/LC change was estimated using the transition matrix probability, the ability to transfer from each land-use to another and Markov Chain. The CA-MARKOV model simulated output data of Markov method using Cellular Automata(CA), Markov chain, multiple decision, and Multi-Objective Land Allocation (MOLA) in 2016, 2030, 2060 and 2100 (Sun *et al*., 2007; Wu *et al*., 2006; Khoi and Murayama, 2010; Fan *et al*., 2008; Coppedge *et al*., 2007; Haibo *et al*., 2011; Eastman, 2006; Takada *et al*., 2010).

Trend analysis of dusty days in base and future period

Trend of the dusty days was analyzed from past to future using Mann–Kendall and Markov Chain method.

Comparing precipitation and dusty days

The negative effect of drought and reduction of precipitation is on vegetation cover; also, they have impacts on soil erosion, often leading to dust hazards.

Results and Discussion

As a hazard, soil dust has serious implications for human society via impacts on health, agriculture, transport and communications. In west of Iran, much attention has been devoted to challenges associated with dust transported over dry lands, deserts, and low and non-vegetation covers to cities. Climate, land use and land cover change effects are the most important challenges for the reduction of soil moisture and raise of wind erosion in the study area; thus, in this paper, LU/LC maps and precipitation were studied.

Land use-land cover (LU/LC) Classification map

In this research, quality and rate of vegetation cover as an important factor for dust generation were investigated using NDVI index in LU/LC classification map in study areas. Table 2 shows the results of four LU/LC classes (water, non-cover, low cover and high cover) in the study region in different years. Some dry land vegetation communities such as temperate grasslands revive tropical rainforests for their species richness (Dengler *et al*., 2014) while their regulating services include important stores of carbon and effects on regional and even global climate (Yatagai and Yasunari, 1995).

The results indicate that areas of water bodies, non-cover and high-cover classes exhibit an increasing trend and conversely for low-cover class. Low vegetation cover which is mainly in and out of rangelands of Iran has a key role in economic and social issues in ecosystems. Vegetation cover is known to have impact mainly on wind erosion so that the intensification of vegetation degradation and growth of non-cover regions area lead to the dust. RRCD trend from 2000 to 2016 showed that intensity of degradation in rangelands was dropped from 30% to 20% in 2000-2012 and 2012-2016, respectively.

Table 2. Area of different Land use-land cover classes (LU/LC) in the study region in 2000, 2012, and 2016

LU/LC Class	2000		2012		2016	
	Area- ha	%	Area- ha	%	Area- ha	%
water	15774	1.70	15159	1.60	16251	1.70
non cover	542521	59.4	574288	62.9	604834	66.3
Low- vegetation	280540	30.7	203952	22.3	180602	19.8
High -vegetation	73480	8.0	118917	13.0	110629	12.1
Total	912317	100	912317	100	912317	100

Accuracy

Accuracy of the classified maps was evaluated using error matrix. The overall accuracy, confusion matrix, and also Kappa index for the observed and predicted LU/LC maps by the means of MODIS images for 2000, 2012 and 2016 are shown in Figs. 3 and 4. The main emphasis for accuracy assessment of pixel selection was on areas that could be clearly identified on MODIS image, Google earth and Google Map. A total of 126 points in different LU/LC classes were created in the classified image of the study area. The Accuracy Assessment Cell Array Reference column was filled according to the best guess of each reference point.

The results of comparing the observed and predicted LU/LC classes in 2016 and 2000 (Table 3) indicate that total absolute value of error is 5.49%. The most and least error rates are for non-cover and water body classes, respectively.

Transmission probability matrix of LU/LC classification map in different periods (Table 4) shows that the most durability and stability are for water body and high vegetation cover class in 2000-2012, 2000-2016, 2000-2030 and 2000-2060. Probability of changing from a class to another varies for different LU/LCs (Figs. 3 and 4) during the times. Probability of changing from water body, high-cover and low-cover (rangeland) classes to non-cover class was higher than 55% from 2000 to 2016. Durability of non-cover class was 89% during 2000-2016. Thus, the area of non-cover class reaches to 400 km^2 in the study region. It will continue expanding till 2060 and get more than 62%.

Table 3. Comparison of observed and predicted LU/LC classes in 2016 and 2000

LU/LC Class	Predicted Map, 2016		Observed Map, 2000		Error	
	Area	Percent	Area	Percent	Percent	Abs value %
Water	15001	1.64	16251	1.78	-0.14	0.14
Non cover	581019	63.69	604782	66.29	-2.60	2.60
Low-vegetation	183876	20.15	180602	19.80	0.36	0.36
High vegetation	132383	14.51	110644	12.13	2.38	2.38
Total	912281	100	912281	100	0.00	5.49

Table 4. Transmission probability matrix of LU/LC classification map during 2000-2012, 2000-2016, 2000-2030, and 2000-2060

Duration	Probability of changing from a LU/LC class to another				
	LU/LC Class	Water	Non cover	Low vegetation	High vegetation
2000 to 2012	Water	0.9515	0.0455	0.00	0.0029
	Non cover	0.0009	0.9458	0.0532	0.00
	Low-vegetation	0.00	0.1784	0.7128	0.1088
	High vegetation	0.00	0.0066	0.0668	0.9263
2000 to 2016	Water	0.8705	0.1148	0.0084	0.0064
	Non cover	0.0039	0.8879	0.0952	0.0129
	Low -vegetation	0.0009	0.4154	0.4318	0.1519
	High- vegetation	0.0010	0.0309	0.1703	0.7979
2000 to 2030	Water	0.8660	0.1161	0.007	0.0109
	Non cover	0.0050	0.8914	0.0802	0.0234
	Low -vegetation	0.0012	0.4565	0.3561	0.1862
	High -vegetation	0.0012	0.0523	0.1502	0.7963
2000 to 2060	Water	0.9033	0.036	0.0166	0.044
	Non cover	0.0049	0.9083	0.0641	0.0226
	Low- vegetation	0.0001	0.4546	0.3714	0.1739
	High vegetation	0.0006	0.0417	0.1139	0.8438

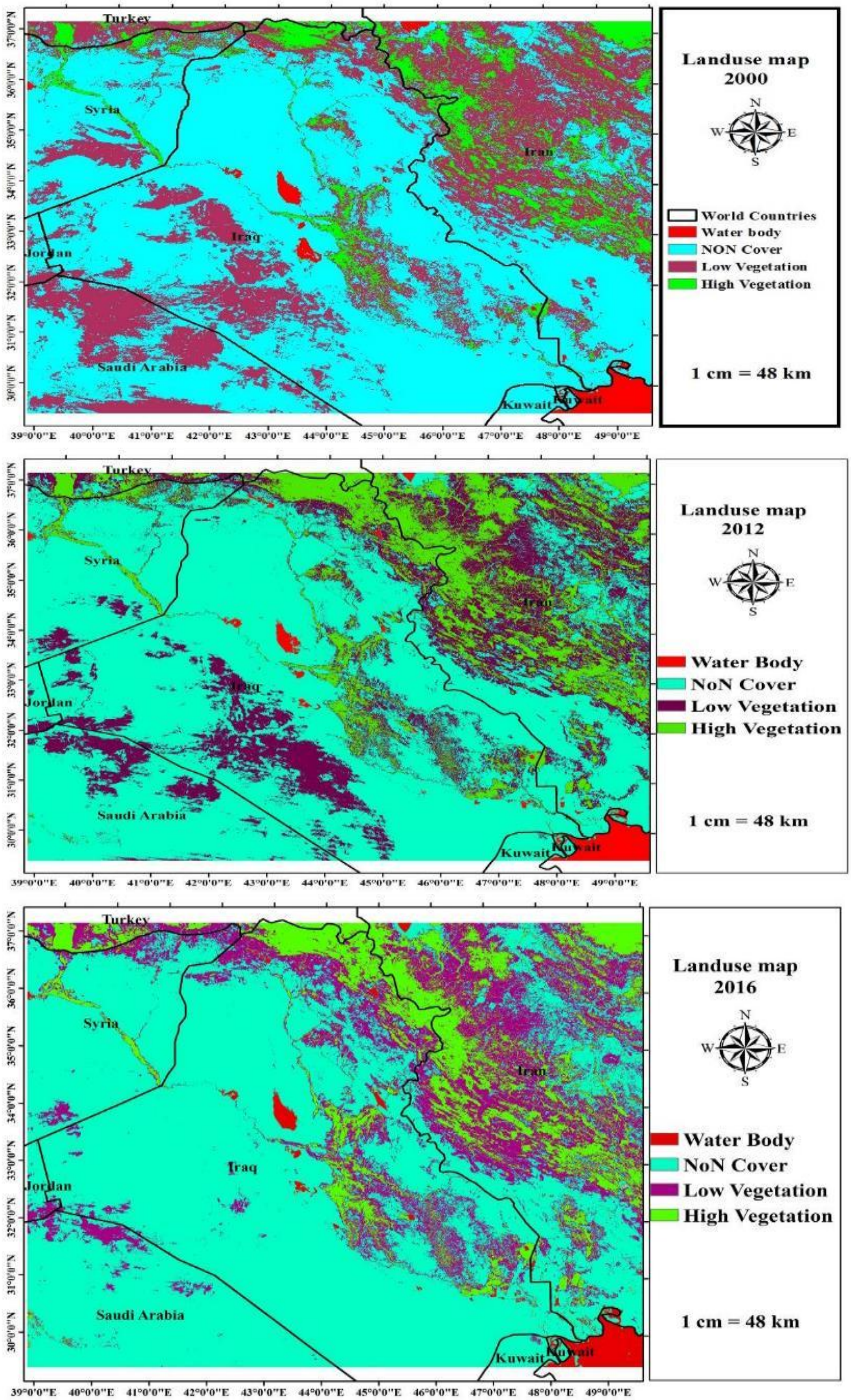

Fig. 3. The observed LU/LC map of area for 2000, 2012 and 2016

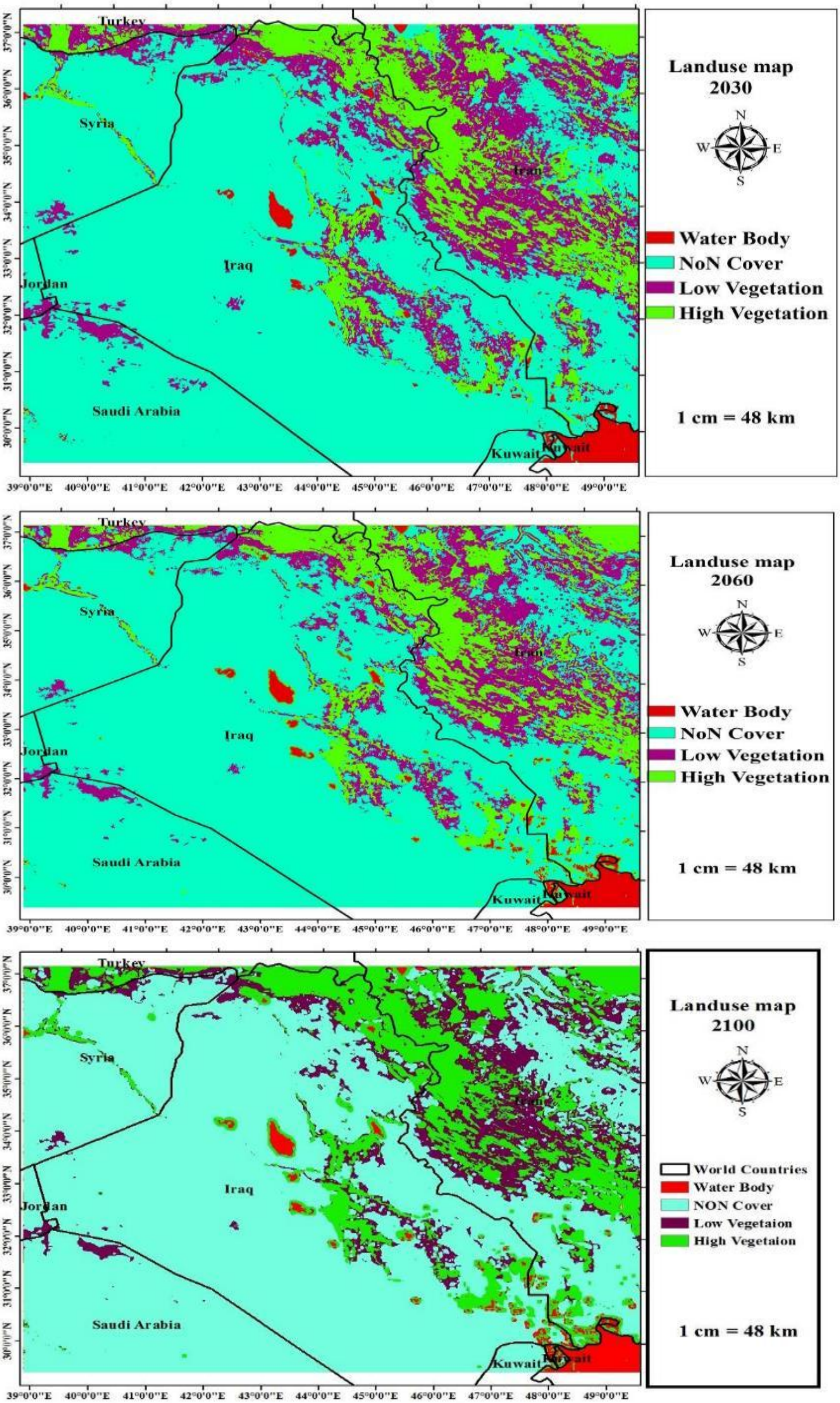

Fig. 4. The predicted LU/LC map of area for 2030, 2060 and 2100

Simulation of LU/LC changes and rangeland degradation for the base and future time

LU/LC map was prepared using transition probability matrix for the end of each period in future (2030, 2060 and 2100). These predicted LU/LC classes were computed on the basis of LU/LC map during 2000-2016 for 2030, 2000-2030 for 2060 and 2000-2060 for 2100. The LU/LC classes areas for the base and future periods were presented in Tables 8. Result illustrated that low-cover and rangeland vegetation cover area has a negative trend, especially during 2000-2012 (Table 5). Transmission coefficient of rangeland and low-cover to non-cover for 2000-12, 2012-16, 2016-30 and 2030-50 were 0.17, 0, 24, .041 and -0.0019, respectively. The results showed that transformation from rangeland and low vegetation cover to non-cover and dry lands will continue till 2060, but it will be stopped and transmission coefficient reaches to -0.0019 from 2060 to 2100.

Table 5. The observed LU/LC classes areas in the base period (2000, 2012, and 2016) and predicted LU/LC classes areas in future (2030, 2060, and 2100)

LU/LC Classes	Observed LU/LC values			Predicted LU/LC values			
	2000	2012	2016	2016	2030	2060	2100
Water	15774	15159	16251	15001	16784	19231	15001
Non cover	542521	574251	604782	581019	617302	637625	581019
Low-vegetation	280540	203952	180602	183876	154549	104886	183876
high vegetation	73480	118917	110629	132383	123630	150522	132383

Trend analysis of LU/LC changes for the base and future times

The results show that there were three significant trends for changes of different classes' areas which among them, non-cover class was more important for dust problem (Fig. 5). Non-cover class area increases from 2000 to 2060. This process of vegetation degradation causes more dust in the study region in future years. Drought is the main natural hazard in most arid and semi-arid regions, and it can decline the forage and moisture availability. The impact of drought on soil moisture and vegetation cover generates and intensifies the dust and sand (McTainsh *et al.,* 2005). According to the analyses of annual rainfall and rainfall days and dusty days in four synoptic stations in west of Iran, it was found that there were inverse relationships especially between rainfall days and dusty days (R^2 =64%). Annual precipitation in parts of Iraq varies between 510 and 730 mm, and occurs between October and April (Szema *et al.,* 2015). Also, the annual precipitation is about 203 mm and 378 mm in Syria and Iran in the study area, respectively.

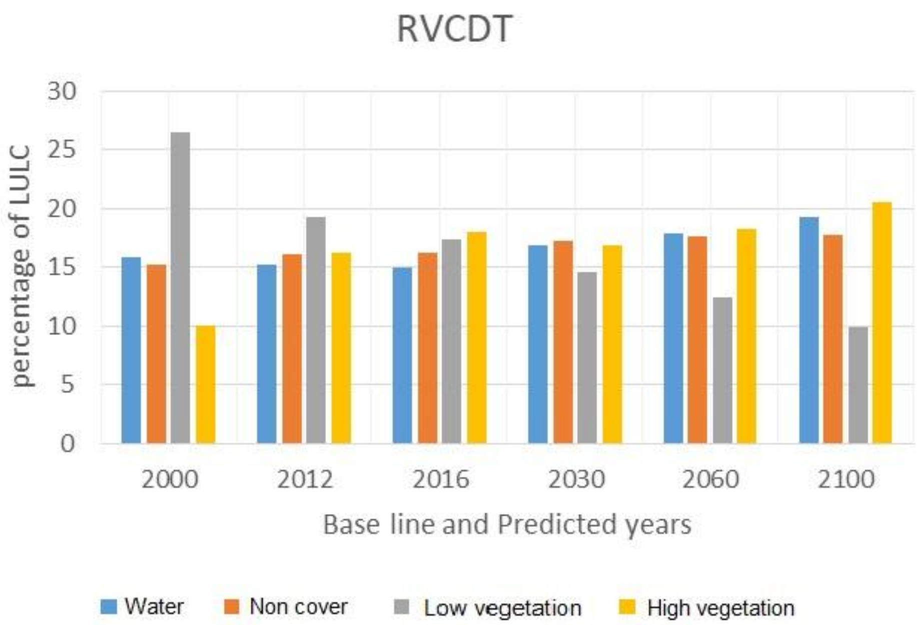

Fig. 5. Regional vegetation cover degradation (RVCDT) and percentage of Land use-land cover (LU/LC) from 2000 to 2100 in the study region

The Findings show that the accuracy of LU/LC mapping is acceptable. Among them, the highest compliance with terrestrial data is found for LU/LC mapping in 2000. The comparison of the accuracy between the predicted and observed values in 2016 indicates that the CA MARKOV method has an appropriate accuracy for prediction of future LU/LC. The acceptable accuracy for LU/LC mapping confirms the findings of Shooshtari *et al*. (2014). The study area was chosen by considering that the main route of dust storms through the western borders of Iran and parts of countries such as Iraq, Syria, Saudi Arabia, Lebanon and Kuwait. Vegetation change maps from 2000 to 2100 illustrate that inefficient management of natural resources and wetlands as well as frequency of droughts have led to vegetation degradation, soil moisture reduction and dust rise.

The results of MARKOV analysis showed that conversion of different land uses to the non-cover land use is the most probable prediction according to transmission matrix of changes prediction from 2000 to 2100 (Table 5). Moreover, the area of non-cover class (Class 2) increases due to reduction of precipitation in this area (Szema *et al*., 2015).

Transforming low vegetation and high vegetation class to no-cover class due to drought and mismanagement caused dust increase in west of Iran. Decreasing of the vegetation area along with increasing of dusty days was well-matched together from 2000 to 2060. By the end of the 21st century, the frequency of dusty days on the study area will rise.

Conclusion

Vegetation cover has been recognized as one of the main factors driving dust in Middle East. RVCD is a complex problem that refers to the constant reduction of precipitation and soil humidity, and also the increase of temperature and evapotranspiration due to human activities and global warming. Strong winds moving across an arid and semi-arid region have made dusty events in the study area. These vulnerable areas can cause many dusty events during warm seasons in west of Iran. The RVCD was studied using series MODIS satellite images from 2000 to 2016. Frequency of dusty days and precipitations are observed in four significant synoptic stations in west of Iran. Trend of the LU/LC changes and degradations was predicted by Markov chain method in 2030, 2060 and 2100.

Probability of changing from water body, high-cover and Rangeland and low-cover classes to non-cover class will be higher than 55% and 62% during 2016-2030 and 2030-2060, respectively. The findings explained that increasing the RRCD leads to rise of dusty days from 2000 to 2016 (baseline time) and 2016 to 2060; then, RRCD will be decreased from 2060 to 2100. The results of Man Kendal method indicated that precipitation and dusty days' trend are positive in the future time up to 2060; as the rainfall amounts and rainfall days rise, the frequency of dusty days will be decrease. Drought is another main driver of vegetation cover change.

This paper examined the supporting evidence for links between RRCD and dust events with an especial focus on regional vegetation based on both RVCD and RRCD. Rangeland and low vegetation cover degradation because of drought and mismanagement have been the most commonly cited causes of desertification in global dry lands for more than 30 years, but the evidence supporting this link is not always convincing (Dengler *et al*., 2014). Nonetheless, overgrazing, desertification and dust storms are frequently connected. Dry lands in general are also important to the Earth system for a range of key resources and other ecosystem services (Yatagai and Yasunari, 1995). The role of Low vegetation and rangeland cover degradation in regional scale is more important than degradation of the other LU/LC classes and the degradation effect is more significant in regional scale than local scale for raise of dusty days; so, appropriate policy and management on these ecosystems are key methods for sustainable development and human health in west of Iran.

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اثر تخریب پوشش مراتع بر افزایش روزهای گرد و غباری غرب ایران

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چکیده. منشا گرد و غبارهای ایران عمدتا از کشورهای عراق و سوریه، عربستان سعودی، کویت و برخی مناطق داخلی کشور می‌باشد که تحت تاثیر خشک‌سالی و تخریب کاربری‌های اراضی/پوشش اراضی در مقیاس منطقه‌ای است. هدف از این تحقیق بررسی اثر تخریب پوشش گیاهی، به ویژه پوشش مرتعی در مقیاس منطقه‌ای بر فراوانی روزهای گرد و غبار غرب ایران (ایستگاه‌های سینوپتیک مراکز استان‌های غربی شامل خرم آباد، اهواز، همدان و کرمانشاه) با استفاده از سنجش از دور و GIS بود. بنابراین کلاس‌های کاربری اراضی/پوشش گیاهی و پوشش مرتعی در مقیاس منطقه‌ای با استفاده از سری تصاویر ماهواره‌ای MODIS و شاخص NDVI از سال ۲۰۰۰ تا ۲۰۱۶ ارزیابی و روند تخریب پوشش گیاهی منطقه‌ای مرتعی با تحلیل زنجیره مارکوف برای سال‌های ۲۰۳۰، ۲۰۶۰ و ۲۱۰۰ پیش‌بینی شد. نتایج مقایسه مقادیر مشاهده شده و پیش‌بینی شده کلاس‌های کاربری اراضی/ پوشش گیاهی در سال های ۲۰۰۰ و ۲۰۱۶ با خطای ۵٪ یکسان بود. یافته‌های این پژوهش نشان داد که احتمال تغییر در کلاس‌های آب، پوشش کم و پوشش زیاد به کلاس‌های بدون پوشش به ترتیب ۵۵٪ و ۶۲٪ در طی سال‌های ۲۰۳۰-۲۰۲۰ و ۲۰۶۰-۲۰۳۰ خواهد بود. پایایی کلاس بدون پوشش در سال‌های ۲۰۱۶-۲۰۰۰ حدود ۸۹٪ است و بنابراین مساحت کلاس غیر پوشش در منطقه مورد مطالعه به ۴۱۰ کیلومتر مربع خواهد رسید. به طورکلی می‌توان اشاره کرد که افزایش تخریب پوشش گیاهی مرتعی در مقیاس منطقه‌ای و افزایش خشک‌سالی به طور عمده موجب افزایش روزهای گرد و غباری از سال ۲۰۰۰ تا ۲۰۶۰ می‌باشد.

کلمات کلیدی: روند تخریب، پوشش مرتع، روزهای غباری، زنجیره مارکف، ایران