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EVALUATING HABITAT OF HOUBARA BUSTARD (*CHLAMYDOTIS UNDULATA*) THROUGH TRENDING OF VEGETATION ACTIVITY IN CHOLISTAN DESERT OF PAKISTAN

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Abstract

In the present study, the habitat of Houbara Bustard was evaluated in Lal Suhanra National Park (LSNP) of Cholistan desert, Pakistan using remote sensing data of LANDSAT-5 and MODIS hyper-temporal vegetation index data of 2000-2012 period. Trend analysis of Normalized Difference Vegetation Index was performed using seasonal Mann-Kendall test to understand the distribution and projected status of the habitat. Over 76% area of the LSNP comprising of sand dunes, sandy/open shrubs, sandy (barren) and open shrubs was identified as the most suitable habitat for Houbara. Majority of the LSNP area exhibited stable trend in land cover/vegetation activity, e.g. about 7% land cover indicated progressive and 4% regressive trend, while 89% land cover exhibited stability (significant at $p<0.05$) in the LSNP. The progressive trending was likely because of increase in rainfall, while the regressive trending was due to increase in sunlight. The <1% regressive trend observed in classes like sand dunes, sandy/open shrubs, sandy (barren) and open shrubs points toward sustainability of the habitat in the LSNP. The MODIS based VI and time series proved useful in inferring trends in the vegetation activity in this region. Seasonal changes in the habitat of Houbara need regular monitoring and an in-depth research in context of future changes in climate and land use. A participatory approach based on concerted efforts would be effective in conserving this precious bird and its habitat on long-term basis in the region in future.

Keywords: vegetation index, Mann-Kendall, remote sensing, natural habitat, desert environment

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Introduction

Pakistan has got global importance due to its location on the flyway of birds travelling during annual migration to Central Asia and Northern India. The birds usually follow Indus valley which provides winter refuge for millions of migratory ducks, geese, flamingoes, houbara bustard and other bird species which return to their summer breeding grounds in the northern hemisphere. In recent time vulnerable species have become one of the significant threats to biodiversity conservation. According to Christianou and Ebenman (2005) destruction and fragmentation of natural habitats and climate change induced by human involvement have greatly influenced the ecosystems during the recent century. Houbara Bustard (Chlamydotis undulata) is a desert and semi-desert dwelling member of the Otididae, classified as vulnerable by the IUCN (International Union for Conservation of Natural Resources) because of rapid change in its population owing largely to unsustainable hunting as well as habitat degradation in the recent decades (IUCN, 2012; Dawn, 2020; Latif, 2020). Its habitat distribution ranges from arid and semi-arid areas of Middle East to Central Asia, and few species of it migrates to Pakistan every year between November and December from Mongolia, Siberia and Central Asian republics for wintering (Gao et al., 2009). Several species of the bird become highly vulnerable due to factors like habitat degradation, habitat loss, fragmentation and unchecked hunting in the area (Tourenq et al., 2005; Gao et al, 2009; Latif, 2020).

In Pakistan, it is found mainly in the semi-arid/arid deserts of Punjab, Balochistan and Sindh provinces (Dawn, 2020). The estimated population of Houbara was 5,302 individuals in Punjab during December 2019 surveys, which had shown decrease in Cholistan desert, i.e., from 4,299 in 2017 to 3,575 in 2019 (Dawn, 2019). The high rates of species loss may cause series of secondary extinctions in ecological communities. Remote sensing (RS) technology has advantage to monitor changes in habitat distribution, degradation and land use change. Changes in biophysical factors like vegetation growth and productivity can be effectively monitored through integration of remote sensing and geographic information systems (GIS) techniques (Kumpula et al., 2002). Satellites generating coarse resolution data are capable of observing large swaths of the earth surface resulting in image time series with high temporal resolution (de Beurs and Henebry, 2005). Moderate-Resolution Imaging Spectro-radiometer (MODIS) land products are freely available cloud-screened surface reflectance data (Friedl et al., 2002; Justice et al., 2002) that have been widely applied for monitoring such as of rangeland production (Reeves et al., 2006; Xu et al., 2007; Yu et al., 2010; Yang et al., 2019) and land use/land cover changes (Tang and Zhang, 2002; Langner et al., 2007; Haque and Basak, 2017). Normalized Difference Vegetation Index (NDVI) has been used effectively to monitor the status, distribution and trends of biomass and vegetation health (Martínez and Gilabert, 2009; Duarte et al., 2018) and to evaluate seasonal and inter-annual changes in arid rangeland (Paudel and Andersen, 2010). It is important to understand the breeding habitat characteristics of Houbara, suitable sites for the breeding and their distribution in the landscape for biodiversity conservation.

In the present study, the habitat of Houbara was evaluated through trend analysis of land cover/vegetation activity in Lal Suhanra National Park (LSNP) of Cholistan desert, Pakistan using MODIS hyper-temporal vegetation index of 2000-2012 period. Trend analysis of Normalized Difference Vegetation Index was performed using seasonal Mann-Kendall test to understand the distribution and projected status of the habitat.

Description of the study area

The study area is located between longitudes 71° 48' - 72° 08' E and latitudes 29° 12' - 29° 28' N in the Cholistan desert of Pakistan (Figure 1). Cholistan desert (locally known as *Rohi*) lying in the Bahawalpur district of the Punjab province is crossed by the dried-up bed of the Hakra River (Scott, 1989). In Punjab, the total wintering habitat of Houbara Bustard is over 32,300 km^2, in which Cholistan shares about 22,900 km^2 (70.9%). The climate is arid subtropical/continental, characterized by hot summers, mild winters and erratic rainfall. Mean annual and monsoon (July-September) rainfall are 160 mm and 108 mm (1957-2013 period), respectively. Average temperature ranges within 34-37°C during summers and within 14-16°C during winters. The geomorphology varies between fairly flat and undulating sand dunes ranging up to 1 ha in extent and 4 m in height. The area has a gradual natural slope towards south. Soils here are preponderantly sandy loam, with clay flats (dhars) between the sand dunes.

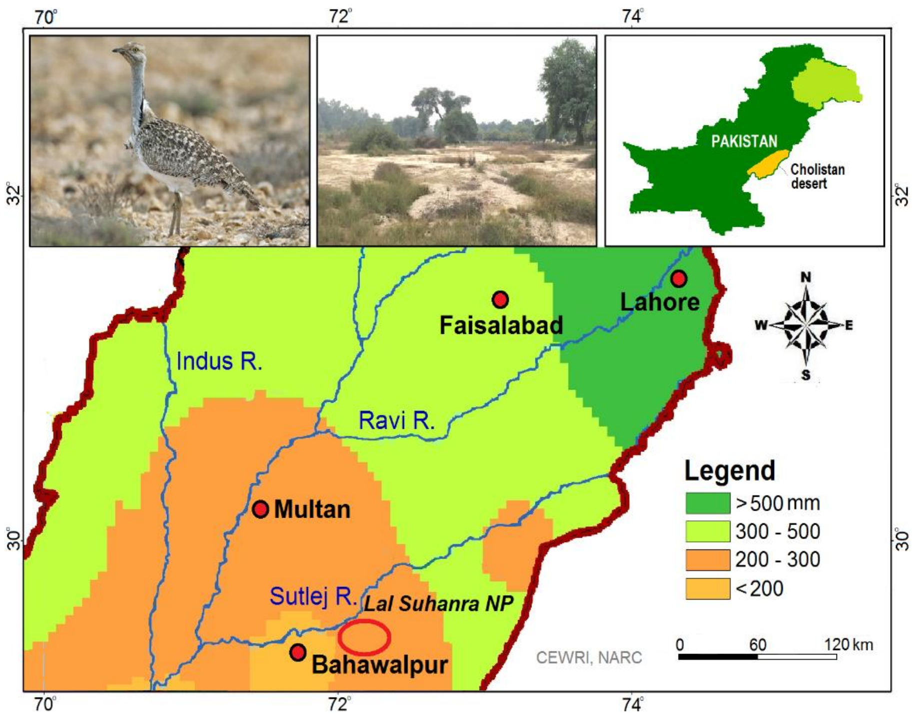

Figure 1. Location of the Lal Suhanra National Park in the Punjab province of Pakistan

Major flora and fauna

The flora mainly consists of xeromorphic species. Major part of the LSNP has a sandy desert character and is influenced by typical desert vegetation mostly appearing in patches (Figure 1) where soil moisture availability is relatively better (Khan and Chaudhry, 1987). The vegetation in these tracts is dominated by desert modified species like *Calligonum polyonoides*, *Aristidadepressa*, *Citruluscolocynthis*, *Lasiurussindicus*, *Dipterygium glaucum*, *Crotalaria burhia* and *Neurada procumbens* stand for typical flora of the Lesser Cholistan (Rao et al., 1989). The annual rainfall in the eastern region of the desert is comparatively high (200 mm) so it contains relatively more vegetation than the southern region that receives less than 100 mm rain annually (Arshad et al., 2008). The main plant communities here include tropical thorn forest, influenced by *Acacia nilotica*, *Suaeda* - *Salsola scrub* and *riverine Tamarix* forest. Impenetrable stands of kana (*Saccharum spontaneum*) grow along the margins of Patisar Lake and *Salvinia natans* covers much of the shallower waters (Sheikh, 2011). The commonly seen animals in LSNP are hog deer, wild boars, ravine deer, mongoose, black buck and blue bull. Fox, jackals, hares, pea fowl, porcupines, arks, owls, and hawks are also found in large numbers (Scott, 1989; Sheikh, 2011).

Material and methods

Data used

Primary data used consisted of Landsat 5 TM (Thematic Mapper) cloud-free scene of June 5, 2011 (Path-Row: 150-40) and MODIS vegetation index (VI) time series (MOD13Q1) in 16-day maximum value composite at 250 m spatial resolution over the period 2000-2012 to observe spatial trends in the vegetation activity in the study area. The MOD13Q1 product was downloaded from Land Processes Distributed Active Archive Center (LPDAAC) data pool (ftp://e4ftl01.cr.usgs.gov/MOLT/MOD13Q1.005/). The climate data (temperature and rainfall) of Bahawalpur meteorological station (Longitude 71° 47'E, Latitude 29° 24'N & Altitude 116 m) was collected on daily time scale since 1957 from Pakistan Meteorological Department (PMD). LSNP boundary information was acquired from the provincial department of Forest and Wildlife. Field survey was conducted during April, 2012 using a pocket size Global positioning system (GPS) having horizontal accuracy of within 3 m to collect ground control points and land cover information from the study area.

This study had two phases: 1) perform land cover mapping of the study area with aim to identify the potential habitat of Houbara Bustard and b) evaluate progressive (increasing), regressive (decreasing) or stable trends in land cover/vegetation activity. The flow chart of the methodology adopted in the present study is shown in Figure 2. The image was georeferenced using Universal Transverse Mercator (UTM: Zone 42) project system. Image classification was performed in ERDAS Imagine 8.3 software using supervised classification algorithms following maximum likelihood rule – the most common and reliable method from the viewpoint of probability theory. Maximum likelihood classifier assumes normal or near normal spectral distribution for each feature of interest and is based on the probability that a pixel belongs to a particular class and takes the variability of classes into account by using the covariance matrix. Major land cover identified in the field include: sand dunes, agriculture, plantation, sandy (barren/open shrubs), trees, open shrubs, urban area and water. In the false color composite of bands 4, 3, 2 (Red, Green, Blue) of LANDSAT-5 image, vegetation is visible in red, moist areas in dark color shades, while open sand areas appear in light to dark grey shades within and around the study area (Figure 3). A sub-set image was extracted from the LANDSAT-5 image data with the help of defined area of interest (AOI) of the study area. Preliminary 15 land cover classes were generated through selection of 3-5 training samples in each land cover for spectral classification of the image. A confusion matrix was created to calculate accuracy descriptors such as kappa statistic, user, producer and overall accuracy (Congalton, 1991). These classes were finally recoded into 9 classes according to the defined classification scheme. The accuracy of the resulting map was assessed through comparison with the vegetation community map of the LSNP generated through predictive modeling.

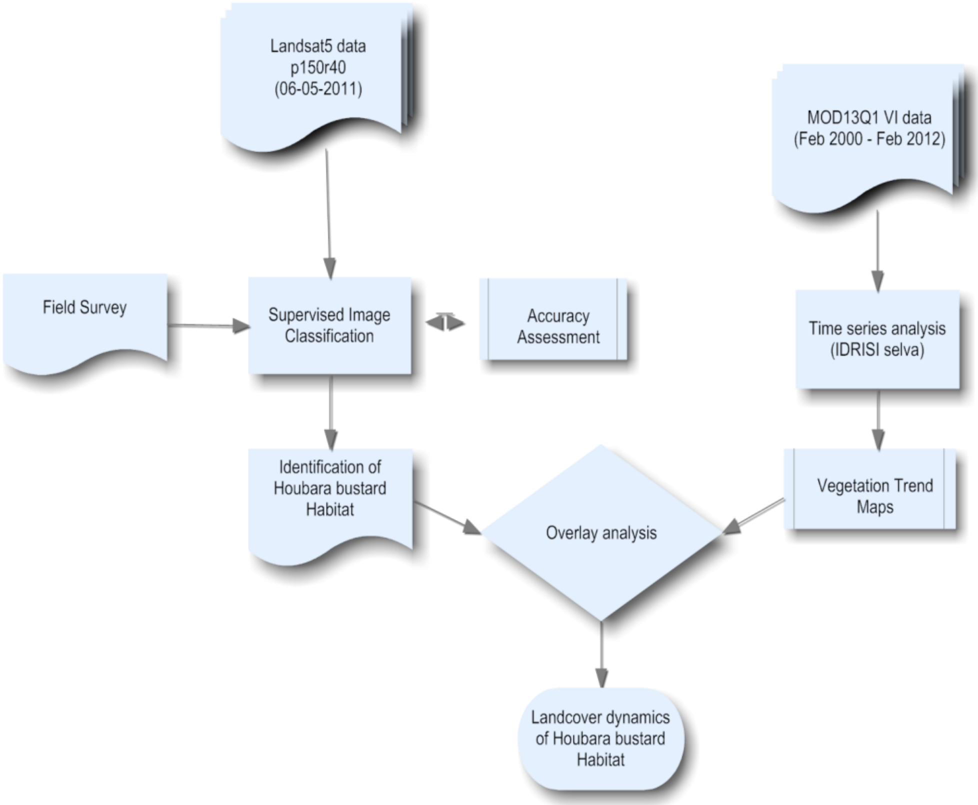

Figure 2. Flow chart of methodology adopted in the present study

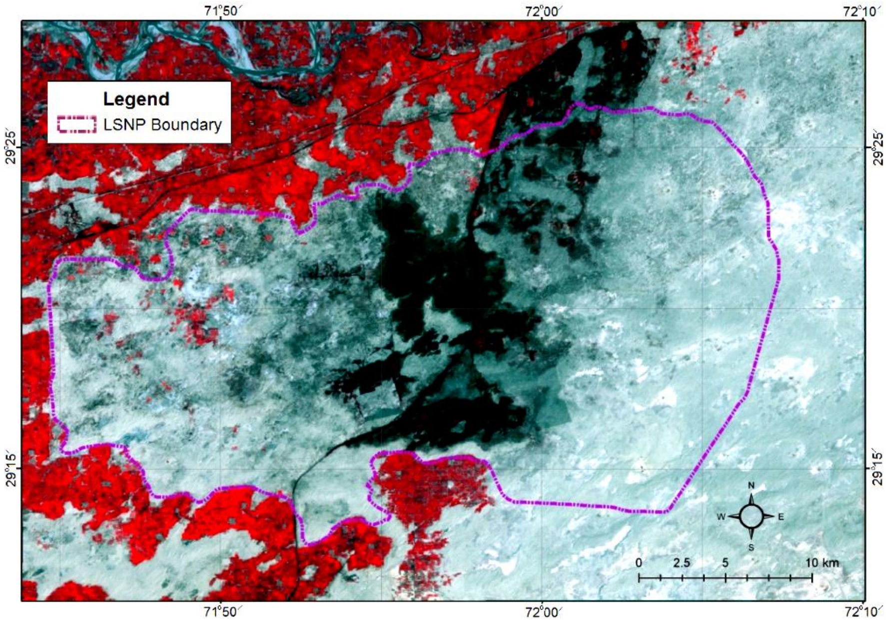

Figure 3. False color composite of Landsat-5 image (Bands 4,3,2: RGB) of the study area

Analysis of Time-series MODIS derived NDVI

NDVI was used as proxy for trend analysis of each land cover/vegetation activity. This vegetation index is primarily adopted to analyze the green vegetation in an area as healthy vegetation absorbs most of the visible light and reflects a significant portion of the near-infrared light that fall on it (Wang et al., 2011). Trend analysis was performed on NDVI using seasonal Mann-Kendall test (Gilbert, 1987). Reflectance values of Near Infrared (NIR) and R (Red) bands of the electromagnetic spectrum are usually used to determine NDVI for monitoring crop growth and discriminating vegetation vigor in the image as follows (Zhao et al., 2005; Ashraf et al., 2016).

$$NDVI = (NIR - R) / (NIR + R) \quad (1)$$

The index values range from -1 (usually water) to +1 (strongly vegetative growth). Seasonal Mann-Kendall test was chosen to test the direction (positive and negative) and statistical significance of change in two series and their anomalies. First each periodic sub-annual interval is evaluated for significant monotonic trends based on Kendall's 'S' score and its variance and then a normalized test statistic 'Z score' and associated probability is calculated (Kendal, 1975). The statistic S can be determined through Eq. 2.

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k) \quad (2)$$

$$\text{sgn}(x_j - x_k) = \begin{cases} +1, if(x_j - x_k) > 0 \\ 0, if(x_j - x_k) = 0 \\ -1, if(x_j - x_k) < 0 \end{cases} \quad (3)$$

Where n denotes the number of sample, x_k and x_j are from k=1, 2, …., n and j=k+1, …., n. If n is greater than 8, statistics S approximates to normal distribution. The mean of S is O and the variance of S can be acquired as follows:

$$\text{var}(S) = \frac{n(n-1)(2n+5)}{18} \quad (4)$$

Then the test statistics Z can be given by Eq. 5.

$$Z = \begin{cases} \frac{S-1}{\sqrt{var(S)}}, if\ S > 0 \\ 0, \quad if\ S = 0 \\ \frac{S+1}{\sqrt{var(S)}}, if\ S < 0 \end{cases} \quad (5)$$

An increasing trend is inferred if Z is positive or decreasing if it is negative at a probability greater than the level of significance ($\alpha \leq 0.05$) and no trend if probability is less than the level of significance (Alcaraz-Segura et al., 2009).

Results and discussion

Climate variability and trend analysis

Mean monthly maximum temperatures were 41.7°C during month of May, 41.1°C in June and 39.8°C in July, while minimum temperatures observed in these months were 26.2°C, 28.3°C and 29.3°C respectively in the study area (Figure 4). The lowest values of temperature maximum and temperature minimum were observed in the month of January, i.e., 20.2°C and 6.3°C, respectively. According to Ashraf and Rehman (2019), the mean annual weighted temperature exhibited a rising trend in the Punjab province during 1970-2014 period. The mean monthly rainfall was >30 mm during the months of July and August, while it was <5 mm during months of November and December. The time-series data of annual as well as monsoon rainfall indicated rising trends at Bahawalpur station. The rainfall exceeds 100 mm in 77% cases at annual and in 44% cases at monsoon level during 1957-2013 period. Furthermore, the rainfall was >200 mm in 15% and 5% cases at annual and monsoon levels during this period, respectively. In almost 79% cases, the contribution of monsoon rainfall in the annual rainfall was more than the non-monsoon rainfall during the 57-year period (Figure 5).

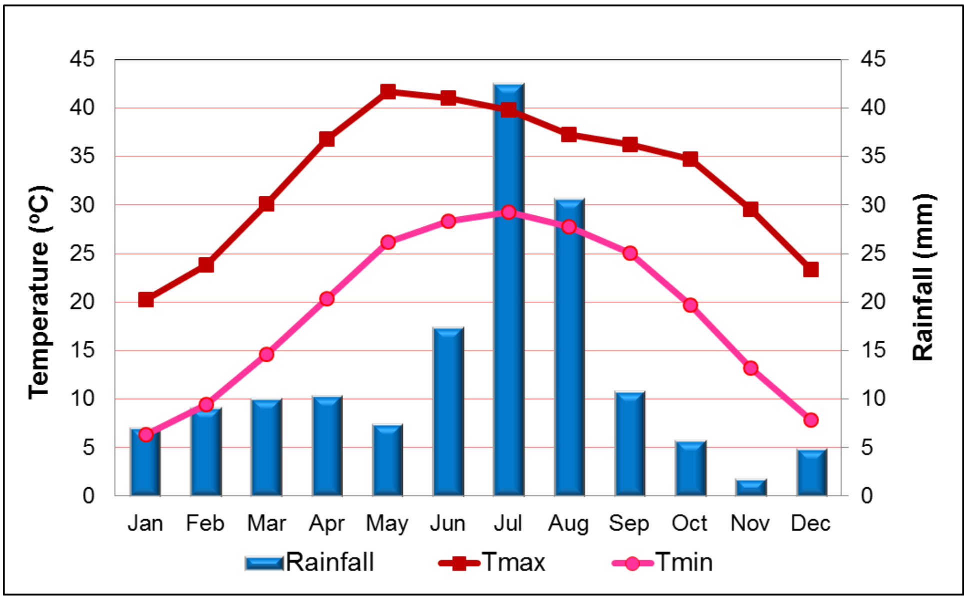

Figure 4. Mean monthly temperature maximum (Tmax), minimum (Tmin) and rainfall at Bahawalpur station

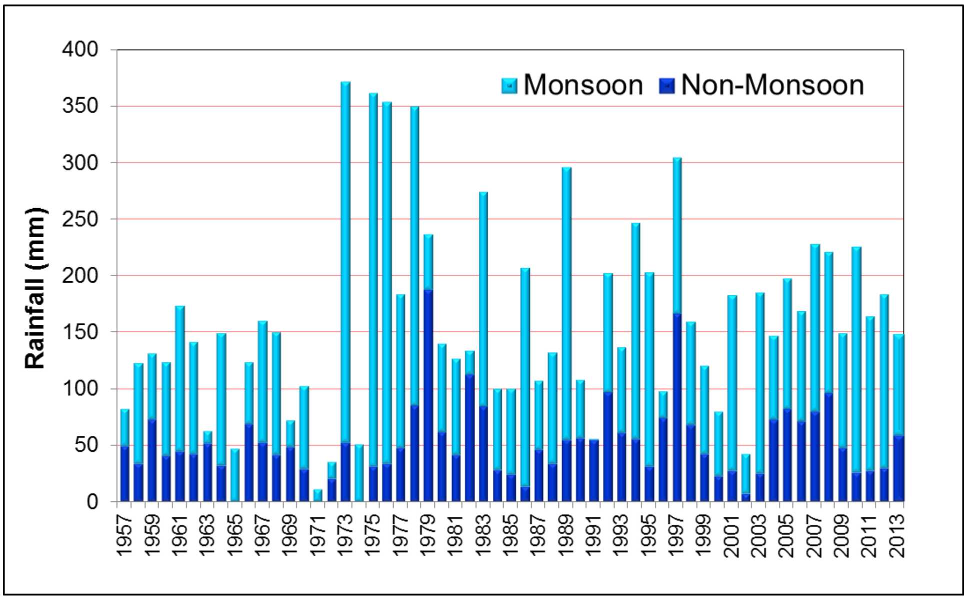

Figure 5. Annual rainfall (monsoon and non-monsoon) variability at Bahawalpur station

Land cover distribution analysis

The major land cover types identified in the LSNP through image classification were sand dunes, agriculture, plantation, sandy (bare), sandy/open shrubs, trees, open shrubs, settlements and water in the study area. The overall accuracy of the land cover map achieved was 73.3% with Kappa quotient value of 0.66 and the maximum possible un-weighted Kappa value of 0.86. The both producer and user accuracies were greater than

57% for all land cover classes except for sandy (barren) and sandy (open shrubs) classes that had user accuracy of about 46.7% and 46.2% respectively (Table 1).

Table 1. Accuracy assessment of the image classification performed for land cover analysis in the study area

	Land cover	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**	**User Accuracy**
1	Water bodies	**10**									10	100%
2	Sand dunes		**7**								7	100%
3	Agriculture			**8**	1			1			10	80%
4	Plantation			2	**7**			3			12	58.3%
5	Sandy / open shrubs		2			**6**	3		2		13	46.2%
6	Sandy (barren)		1			**4**	7			3	15	46.7%
7	Trees				2			6			8	75%
8	Open shrubs								8		8	100%
9	Settlements									7	7	100%
Total Possible		**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**		
Omissions		0	3	2	3	4	3	4	2	3		
Commissions		0	0	2	5	7	8	2	0	0		
Correctly classified		10	7	8	7	6	7	6	8	7		
Producer accuracy		100%	70%	80%	70%	60%	70%	60%	80%	70%	Overall accuracy= 73.3 %	

The land cover analysis indicated sandy/open shrubs over 38.6% area, open shrubs 27%, tree cover 18.3% and sand dunes 10% (Table 2 and Figure 6). The open shrubs class consists of natural vegetation of desertic nature like *Acacia jacquemontii, Haloxylon recurvum, Ottochloa compressa, Lasiurus scindicus* and *Prosopis cineraria.* The tree cover consists mainly of naturally and artificially grown trees along the canal and elsewhere. The sand dunes are adorned with desert plants which provide food to Houbara besides other birds and animals. The agriculture land comprised of rainfed and irrigated cultivation. The planted area over 3.1% area comprises of mix forest plantation, e.g. *Eucalyptus camaldulensis*, *Prosopis cineraria, Dalbergiasissoo*, and *Acacia nilotica* generally grown for timber purpose (Hameed et al., 2011). The sandy (barren) land found over 1.3% in the LSNP consists of non-vegetated or least vegetative areas where the substrate or soil exposure is clearly apparent. Settlements were found over 8 ha area of the LSNP constituting mainly built-up land, man-made structures and activities of various scales. The water bodies both natural and manmade were found over

230 ha area comprising mainly of Patisar Lake, ponds and channels. The lake is fed by the Desert branch of the Bahawalpur Canal, besides excess water from the irrigated land. The lake is an important wetland for both resident and migratory bird species including Houbara bustard. The land cover types, i.e., sand dunes, sandy/open shrubs, sandy (barren) and open shrubs (about 77% area: 28,798 ha) form the most suitable habitat of Houbara in the LSNP (Table 2).

Table 2. Extent of various types of land cover assessed in the LSNP area

S.No.	Land cover	LSNP Area (ha)	% Area
1	Sand dunes	3753	10.0
2	Agriculture	400	1.1
3	Plantation	1144	3.1
4	Sandy / open shrubs	14464	38.6
5	Sandy (barren)	474	1.3
6	Trees	6846	18.3
7	Open shrubs	10108	27.0
8	Settlements	8	0.0
9	Water	230	0.6
	Total	37426	100.0

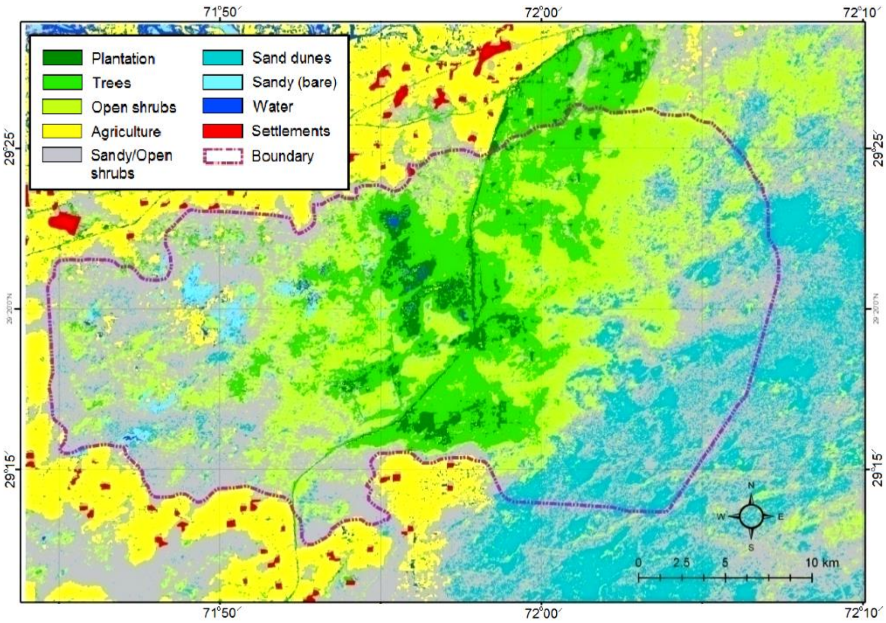

Figure 6. Land cover distribution in the study area

The NDVI time-series analysis using Mann-Kendall Z score revealed pixel values varying between –11.8 and 16.1 in the area (Figure 7). The positive trending values are mostly visible in the eastern and the negative values in the western parts. The agriculture land in the periphery of the LSNP, plantation and trees within the

LSNP appear to exhibit negative trending values, while the sandy/open shrub class shows least z score values.

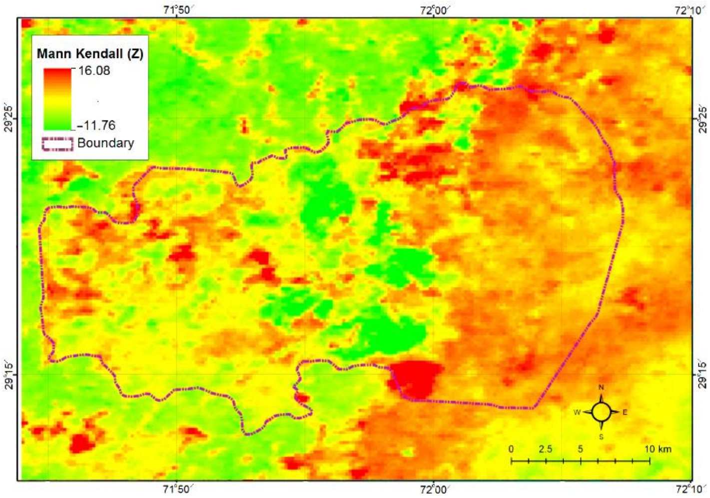

Figure 7. Mann-Kendall Z score for the NDVI time-series analysis

Over progressive trend was observed in about 7% of the land cover and regressive trend in 4% of the land cover, whilst 89% of the land cover exhibited stability (significant at $p<0.05$) in the LSNP (Table 3 and Figure 8). The highest regressive trend was exhibited by the trees and the lowest by the sand dune class. When sunlight increases it shows regressive trend and when rainfall increases it shows progressive trend. The sandy/open shrubs indicated 2.8% progressive, 97% stability and only 0.2% regressive trend which appear favorable in view of the habitat conservation. Houbara generally prefers low dense shrubs and grasses within its natural habitat. According to some studies, the vegetation with <1 m height is usually the favorable daytime habitats for several Houbara species (Yang et al., 2003; Islam et al., 2013). They rarely prefer to nest in dense vegetation and in depressions, rather concentrate their foraging at the edges of wadis (Asadalla et al., 2015). The selection of open areas with sparse vegetation avoiding densely and tall vegetation sites by nesting females of Houbara is likely to be vigilant from the predator like fox which live in the similar habitat (Yang et al., 2003). The open shrub class indicated 2.4% progressive trend, 97.2% stability and only 0.4% regressive trend also pointing toward better condition for the Houbara habitat in the area. According to Khan (2014), maximum number of Houbara birds were found near shrubs and grasses followed by barren land and water bodies in the western part of Pakistan. Moreover, plant species richness and distance to shrub by patches are also some other factors determining nest-site selection by the Houbara. The regression trend observed in the open shrub class is likely because of grazing pressure as according to Yang et al. (2003), some xeromorphic plant species do survive during severe droughts but undergo tremendous grazing pressure leading to partial eradication of the vegetation. Similarly, climate change effects like low rains usually cause gradual shrinkage of wetlands and diminishing of natural vegetation at places forcing the birds to move to other sites (Latif, 2020).

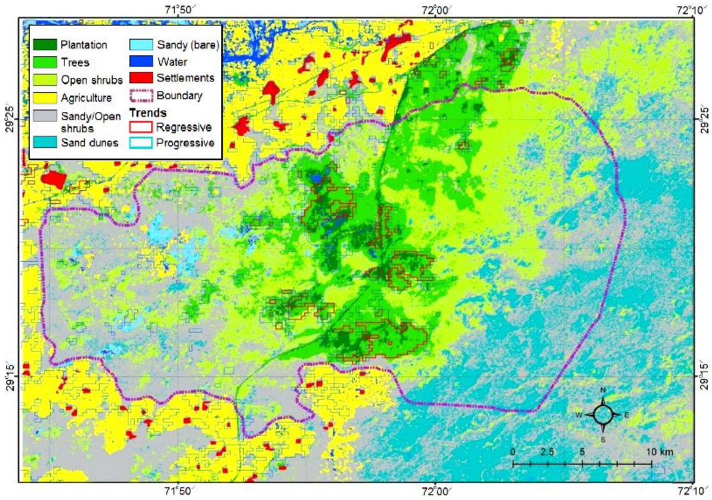

Figure 8. Trending of vegetation activity in the study area

According to several studies, NDVI is positively correlated with rainfall in grasslands of arid and semi-arid regions (Guo et al., 2014; Yang et al., 2019). Ashraf et al. (2016) observed increased NDVI values in the rainfed region of the Punjab area owing to high moisture conditions beside other factors. An increasing trend in vegetation activity was observed over 406 ha of sandy/open shrubs and 243 ha of open shrubs (Table 3). The open sandy areas with short shrubs (e.g. ranges in cover between 1–15%) alongside the dense patches of high shrubs are generally the most favorable habitat of Houbara Bustard (Mian, 2003), and about 90% of the nest sites chosen by the bird were along the edges of dense vegetation in the flat areas (Yang et al., 2003). The <1% decreasing trends observed in the sand dunes, sandy/open shrubs, sandy (barren) and open shrubs classes points toward sustainability of the habitat in the LSNP.

Table 3. Trends in land cover/vegetation activity (values in hectare and percentage within brackets) in LSNP (Note: The land cover classes in bold represent suitable habitat of Houbara)

S.No.	Land cover	Progressive	Stable	Regressive	Total
1	**Sand dunes**	5 (0.1)	3748 (99.9)	0.1 (0.0)	3753 (100)
2	Agriculture	74 (18.5)	319 (79.7)	7 (1.8)	400 (100)
3	Plantation	369 (32.2)	405 (35.4)	370 (32.3)	1144 (100)
4	**Sandy / open shrubs**	406 (2.8)	14028 (97.0)	30 (0.2)	14464 (100)
5	**Sandy (barren)**	8 (1.6)	466 (98.4)	0.2 (0.0)	474 (100)
6	Trees	1460 (21.3)	4359 (63.7)	1027 (15.0)	6846 (100)
7	**Open shrubs**	243 (2.4)	9829 (97.2)	37 (0.4)	10108 (100)
8	Settlements	0.1 (1.6)	7 (98.4)	-	8 (100)
9	Water	50 (21.8)	157 (68.0)	23 (10.1)	230 (100)
	Total	2614 (7.0)	33318 (89.0)	1494 (4.0)	37426 (100)

Conclusions

In the present study, the habitat of Houbara was evaluated through trend analysis of land cover/vegetation activity in Lal Suhanra National Park (LSNP) of Cholistan desert, Pakistan using RS data of LANDSAT-5 and MODIS hyper-temporal vegetation index data. Over 76% area of the LSNP comprising of sand dunes, sandy/open shrubs, sandy (barren) and open shrubs was identified as the most suitable habitat for Houbara. About 7% of the land cover/vegetation activity indicated progressive, 4% regressive and 89% stable trend (significant at $p<0.05$) in the LSNP. When sunlight increases it shows regressive trend and when rainfall increases it shows the progressive trend. The <1% decreasing trends observed in the sand dunes, sandy/open shrubs, sandy (barren) and open shrubs classes points toward sustainability of the habitat in the LSNP. The MODIS based VI and time series proved useful in inferring trends in the vegetation activity in this region. Seasonal changes in the habitat of Houbara and its response to current and future changes in climate and land use need an in-depth research, besides regular monitoring of the habitat based on field investigations and GIS modeling. Also an effective management and conservation of the natural resource are essential to sustain the habitat on long-term basis in this region in future.

Conflict of interest

None

Authors' contribution statement

R.M. and S.A. conceived the idea, collected data, developed databases and wrote the main text, Z.S. provided insight and suggestions to improve the results and A.A. contributed in the results, discussion and editing of the paper.

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