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Does Landscape Change Matter? Change Metrics Analysis, Landscape Level and its Impact on the Bat Population of Thar Desert, Rajasthan

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Study Area: Thar, Rajasthan, India
Coordinates: 27°N 71°E

Key words: Thar, Desert, Bat population, Bat diversity, Microchiropterans

Abstract

Bats use the landscape as their habitat to thrive and survive for years and have high site fidelity for their traditional roosting places. This is highly collaborated with other cofactors like optimum humidity and temperate. Over the years of anthropogenic activities at the landscape level, bats also explore them as an opportunity to expand their species distribution range as well and the same can have a negative impact too. The present study gives an opportunity to understand this in the Thar Desert of Rajasthan and the outcome is interesting to extrapolate the hypothesis. In Western Rajasthan, we explored three major districts namely Jodhpur, Jaisalmer and Barmer. Over the years urbanization in Jodhpur has led to habitat loss for bats, Barmer become a hub of many horticulture crops due to many affirmative and promotional schemes by the Government and large areas of Jaisalmer are now under agriculture, left a negative impact on the vast open habitats in desert country. Bats are very sensitive towards their habitat change and this can be understood from the way landscape-level changes.

Introduction:

On earth, millions of organisms choose thousands of suitable habitats to fulfil requirements to survive and sustain their life and it can be summarized in different land-use classes as it varies from desert to tropical forest. Bats mostly choose forests, woodland, hills, and mountains for their roosts. In the last decades, many changes have occurred in land use patterns due to anthropogenic impacts like intensive agriculture, alteration of pasture land, human settlement, and linear development like road and rail transports. As a result, deforestation and forest degradation have increased due to disturbed wildlife communities and habitat-specific species have been threatened to extinct (Rulli *et al.*, 2021) including bats. These types of land degradation are caused by unsustainable human practices and have a huge impact on the native biodiversity. As of now, 40% of the land surface is covered by Agricultural areas (FAO, 2011; Alpizar *et al.*, 2019) which are increasing gradually (Tilman, 2011). Due to the expansion of many cities and towns, the old trees and microhabitats have vanished so on to a local scale that it decreased the species richness and biodiversity. Many bat roots were affected especially fruit bats. It generates an active link between commercial crops and forests through seed dispersal and controls the insect population (Boyles *et al.*, 2011). Bat hunting strategies, echolocation frequency, body size, and diet composition decide the range of foraging habitat and these ranges are species-specific (Norberg & Rayner, 1987; Arlettaz, 1996; Entwistle *et al.*, 1996; Sierro, 1999; Siemers & Schnitzler 2000). Bats prefer forest or natural vegetation and may use man-made habitats or forest fragments which are more similar to the forest in horizontal and vertical complexity (Estrada *et al.*, 1993) and among bats, insectivores bats are a good indicator of habitat quality (Jones *et al.*, 2009). Forest fragments may increase the mortality of non-adult individuals due to poor dispersal and mobility. The mosaic habitat and continuous forest support the species richness in that area (Estrada *et al.*, 1993). The conservation of forest fragmentation, man-made vegetation and the expansion of the area of vegetation and reducing the distance between the habitats may support bat population and richness in the landscape. Human affects the climate through land use and land cover changes and activities such as growing more and more food crops, rampant cutting of trees, and building more and more cities and townships. Land-use changes largely impact the

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environment (Anaafo, 2015). Due to the construction, single species plantation, deforestation and others, have impacted the soil quality, biodiversity and ecosystem (Kong, 2006). Climate change impacts the species distribution, disturbed patterns, and suitability of land uses (Sleeter *et al*., 2018). In urban areas, buildings and infrastructure trap more sun heat than vegetation and soil and ultimately increase the local temperature with the creation of an urban heat island (Oleson, 2015; Sleeter *et al*., 2018). Urbanization influences the global temperature at a small level but it affects more regionally where urbanization is immense and extensive (Zhou *et al*., 2004; Yang & Chen, 2011; Hartmann *et al*., 2013). Urbanization locally can influence the ambient temperature over the year and it can influence the species diversity, especially in bats. More expansions of towns and cities can disturb the old bat roosts and its dynamics. These changes become permanent and prominent and it's emphasized to species locally extinct and migrating. Land use changes impact temperature, moisture, seasonal variation of rain, and heat fluxes globally and locally. Forest mostly affects the environment, through deforestation and afforestation.

India is a mega-diverse country and various types of landscapes help to flourish biodiversity. Unsustainable developments are the major factor to impact the land use change. Most of the land in India is under agricultural practice and most of the forests have been converted into farming and plantation. In the Western Ghats, much of the landscape has been dominated by monoculture tea and coffee plantations (Mudappa & Raman, 2007; Wordely *et al*., 2017). In India, much of the land is under the practice of crop production and it produces one of the largest agricultural commodities on the earth (FAO, 2017a; Teluguntla *et al*., 2015; Hinj *et al*., 2020) Some remaining forest patches occupy the 22% of the total area and helps to reduce carbon (Nadagoudar, 2016; Roy *et al*., 2015; Swaminathan & Bhavani, 2013; Tian *et al*., 2014) but due to human population, these landscapes are under pressure to fulfill the demand of the ever-increasing human population. Due to town and city expansion, the requirement for infrastructure has increased rapidly in the last few decades including the road transportation systems, highways, townships, and dam constructions. It threatens biodiversity as many species are more sensitive to habitat loss. During the last decades, the human population of that desert has increased immensely compared to the rest of the world's desert landscapes. The Thar Desert is the most populated desert in the world. A large portion of it lies in Rajasthan and cover 0.32 million km2 and form 10% total geographical area of India. To fulfil the demand of the growing population the government introduced the Indira Gandhi Canal in 1952 and as of now it supplies water for agriculture to Sriganganagar, Hanumangarh, Jaisalmer and Bikaner on the other hand water from the Narmada River is also brought up to Barmer and Jalore. This has changed the life of humans and as it provides water to irrigates 30 to 35 lakh hectares of land (Payal & Poonam, 2020). This caused immense changes in the desert area into a flourishing agricultural landscape and it also influenced the surrounding environment. It changed the ambient temperature and moisture of the surroundings permanently. The direct impact of this can be seen on many desert-adapted flora and fauna. This also forced the biodiversity of arid areas under the threat of local extinction (Tembhurne *et al*., 2020). Three species of bats have been not seen since 1980 in this region, are False-vampire bat (Megaderma lyra), the Dormer's bat (*Pipistrellus dormeri*) and the Egyptian Free-tailed bat (*Tadiarida aegyptiaca*). Interestingly, Fulvous Leaf-nosed bat (*Hipposiderous fulvus*) was rediscovered in the Jodhpur district 37 years (Dookia *et al*., 2017). All these bat species are habitat-specific and during 20-30 years there has been an increase in canal irrigation, humidity and landuse pattern changed into double cropping system which led to various changes in the ecological system of Thar Desert. Many old buildings like old houses have been diminished, destroyed, renovated and converted into heritage hotels and new houses. These new building structures are not habitable for bats to roost. It also changes the roosting site from the micro level to the macro level and leaves a drastic impact on bat diversity and species composition. The floral diversity of the Thar Desert adapted to the harsh environment and mostly is xerophytes. During the last 15-20 years, the agriculture pattern has changed and farmers are now growing fruit-bearing trees. This new type of untraditional way of cropping system also had an impact on bats' diversity. It allowed expending the distribution of Short-nosed fruit bats (*Cynopterus sphinx*) from the Aravalli hills towards the desert area from 2004 onwards (Dookia, 2004). During the present study, a distributional range of extension of Indian fruit bats (*Pteropus medius*) was noticed in more drier parts of Thar Desert like Jalore and Jaisalmer districts respectively. Jaisalmer is one of the driest regions of the state and *Pteropus medius* is the largest bat on the Indian subcontinent, requires nearby perennial waterbodies for daily water drinking and cooling off body temperature during summer and relies on fruit-bearing trees. In Jaisalmer, land use change faces a new dimension of the agricultural system. Many fruit orchards of date palm, *Ziziphus* and Pomegranate have been introduced in this arid land in last 2-3 decades. The present study is an attempt to understand the impact of land use changes on bat diversity at the landscape level in western Rajasthan.

Materials and methods

Bats are largely dependent on the local climate, topography and available landscape for their survival and distribution. To understand this, change detection methods were used.

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For this Landsat satellite data imageries of four decades were taken for landscape-level study and supervised classification was carried out from year 1986 to 2018. The land use land cover change of the three largest districts of western Rajasthan namely Jodhpur, Barmer and Jaisalmer were chosen for this study and classified into seven broad categories, i.e., agricultural land, hills, barren land, water bodies, mining, scrubland and human settlements. There are a total of 272 known bat roosting sites in these districts, out of them only 6 permanent roosting sites where more than one species roosting site was monitored. A buffer of 20 km was taken, with the centre of each roosting site and later outer boundary of all these sites was merged to make a single polygon for landscape level change matrix study. The Google Earth Pro engine was used to study the area and mark a 20 km buffer from the selected roosting sites. The Landsat 5 imagery for the years 1986, 1996 and 2006 and Landsat 8 imagery for 2018 were downloaded from the United States Geological Survey (USGS). The spatial resolution of all imageries was 30m. All the 30m resolution Landsat scenes used in this study were carefully selected from September, and they were without cloud cover. The bats considerably travel between 1 to 20 km home range (Zeale *et al.*, 2012) every night from their roosting sites. During uncertain conditions, it can migrate locally and travel more distance. Therefore 20 km buffer was used for each site to understand the landscape level changes over the four decades. For this, four permanent roosting sites were selected from Jodhpur and one site each for reaming two districts.

Processing of satellite data with Geographical Information System (GIS): After the image was procured, the pre-processing of the image was completed. Pre-processing of satellite images involves the following important steps which were completed using the software ERDAS ImagineTM 15. Satellite images were processed, layer stacking, and sub-setting of the area of interest was done using UTM projecting and unsupervised classification was performed. It is a fast process so good for classifying large areas over multiple images. In the present study, 89 classes were selected with 16 iterations for running the unsupervised classification tool. After the unsupervised classified image is generated, the classes are reduced from the assigned number (89) to the desired number of classes using the Raster recode tool from ERDAS. In the present study, all 89 classes of the unsupervised image were reduced into the 7 following classes:

i. Agricultural-land – An area which is constantly under agriculture, either single cropping pattern or multi-cropping pattern
ii. Barren-land – Those areas or land which has less than one-third of vegetation cover, including barren sand dunes, thin and loose soil, sand, rocks, desert, dry salts or saline beds, exposed rocks, strip mines and gravel pits.
iii. Hills – Small hillocks or liner rocky clusters
iv. Human settlement – Human dwelling units or clustered human settlements.
v. Mining – Open cast mining, stone quarries.
vi. Scrubland – Uncultivated scrubland with perennial shrubs
vii. Water bodies – Small to large water bodies, dry river or stream beds

After the classes were reduced to 7, the utilization of field knowledge with the help of ground truthing was used to potentially make a more accurate classification using the unsupervised classification as a guide. The classified pixels might take a different class than what original is its spectral signature. Hence the classified image was panned with the satellite image and each pixel was assigned the same class as its spectral signature by drawing AOIs (Area of Interest) in ERDAS and by this image cleaning was done. ArcGISTM 10.7.1 and ERDAS 15 were used for satellite image processing and spatial analysis. Garmin 52S GPS was used for the ground truthing and collected the geo-coordinates of location of the all the sites.

The flow chart of the methodology is exemplified in below fig. 1:

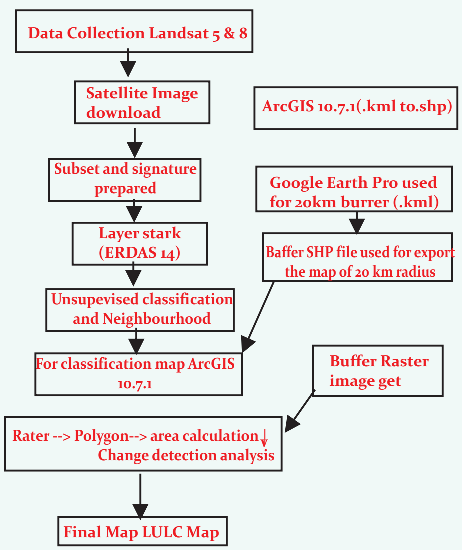

Figure-1: Schematic flow chart showing different stages of image processing

Results

Landscape-level habitat change assessment (land use – land cover analysis)

The desert landscape of western Rajasthan witnessed major land use - land cover changes over the four decades. To understand this, a 20 km buffer of a few permanent roosting sites was created and a total of 5,437 km^2 area was classified under 7 different land-use classes, out of that, 1255 km^2 was for Jaisalmer, 2926 km^2 for Jodhpur and 1256 km^2 for Barmer site.

Jaisalmer site: Jaisalmer is the most arid region of Rajasthan state and is largely dominated by barren sand dunes with xerophyte vegetation over flat lands between sandy habitats. Agriculture mainly depends on the monsoon season, but in the last four decades, some parts of the land have now been irrigated by tube wells and canal systems. The site for LULC classification was on the eastern border of the city, namely Gajroop Sagar Pond and the surrounding. This area of Jaisalmer is surrounded by rocky barren land and xerophytic scrub vegetation. In the last four decades, agricultural land has decreased by 3.05% (38.4 km^2), barren land increased by 1.31 % (16.5 km^2), human settlement increased by 1.35 % (17.04 km^2), scrubland decreased by 0.92% (11.67 km^2), water bodies increased by 0.47% (5.93 km^2) and mining increased by 0.86% (10.84 km^2). In the four decades, agriculture and scrubland have been converted into human settlements, and mining, as well as water bodies, also increased (Table-1).

Jodhpur site: A total of four permanent roosting sites, where multiple species roosting for decades, were selected from the Jodhpur district for this study. All these sites fall within a 20 km buffer of each other, hence these areas were pooled together and a total of 2926 km^2 area was classified to understand the various land use types and changes over the four decades. All sites are also in and around Jodhpur city, which is the second largest city in the Rajasthan state. This urban landscape influences the neighbouring area and changes into human settlements. During last four decades (1986-2018), agricultural land decreased by 7.35% (215.34 km2), barren land increased by 4.21% (123.37 km^2), hills area decreased by 0.54% (15.88 km^2), human settlement increase by 2.88% (84.44 km^2), mining area increased by 3.32% (97.17 km^2), scrubland decreased by 0.99% (29.04 km^2) and water bodies decreased by 1.53% (44.82 km^2). The overall major changes were observed in agricultural land which was converted to barren land and human settlements, whereas hills were converted into human settlements as well as mining areas. Scrubland and water bodies were also decreased into mining and human settlements. It indicates that, due to urban expansion, the available land around the city area was converted into human settlement and other associated requirements. Mining is also a major threat to the habitat of bats species as it destroys the roosting sites of caves, hillocks and crevices (Table-2).

Barmer site: In the Barmer district, only one site was selected for this landscape-level habitat study, i.e., the Kundal region. This is an agricultural-dominated area with a large number of fruit orchards of pomegranate, *Ziziphus* and gooseberry. Barmer and Jalore is the largest producer of the Pomegranate in Rajasthan state (Pagaria *et al*., 2019). In the last four decades, massive land use conversions have been noticed. This was largely from all classes to agricultural land where good availability of groundwater reservoirs is the main source of irrigation. In 1986, the Kundal region was dominated by the sand dunes, which was a major category under barren land and the seasonal Jawai River was the major source to recharge the underground aquifers. Interestingly, in the last decade, the state government started many subsidized farming schemes linked with horticulture, drip irrigation, solar-powered tube wells as well as the construction of large farm ponds (diggi) with government subsidized affirmative schemes or rural development and income generation. This attracted many farmers and almost all privately owned available land (barren land category), which was hardly cultivated in past, is now converted into such horticulture farms. From 1986 to 2018, major change has been observed into increase of agricultural land by 61.10% (767.49 km^2), human settlement increased by 0.64% (8.08 km^2), negligible change in mining, scrub land increased by 0.89% (11.17 km^2), water bodies decreased by 0.85% (10.71 km^2) and barren land decreased by 62.19% (781.20 km^2) (Table-3). The maximum change happened in the barren land category to agricultural land. Basically, this conversion was noticed as a major sand dune habitat is now under horticulture due to state-sponsored subsidized schemes as of now Barmer is one of the major exporters of Pomegranate fruits from Rajasthan.

Change Matrix analysis: For a better understanding of which class was converted into which, a change matrix was generated.

Jaisalmer site: This site is close to a perennial water body, but in the last four decades, urbanization and the demand for land for the construction of human dwelling units caused major land use changes. In the Jaisalmer area, major class change occurs between barren land and agricultural land. Barren land is converted into agricultural land (2288.66 ha.), human settlement (1112.99 ha.) and mining (1035.39 ha.). On the other hand, earlier existing agricultural land also was converted into human settlement (338.06 ha.) and illegal mining (11.73 ha.). Scrub land was also converted into human settlement (379.85 ha.) and mining (33.89 ha.) (Fig. 2, 3 & 4, Table 4).

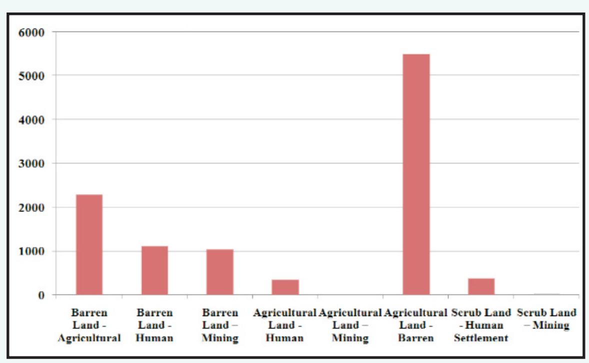

Figure-2: Change matrix and class conversion of Jaisalmer site from 1986-2018

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Table 1. Area class distribution and land use land cover assessment of Jaisalmer site

Classes	Surface land area covered (km2)								Net area change (%)							
	1986		1996		2006		2018		1986-96		1996-2006		2006-18		1986-2018	
	Km2	%	Km2	%	Km2	%	Km2	%	Km2	%	Km2	%	Km2	%	Km2	%
Agricul. Land	73.64	5.87	47.87	3.81	81.96	6.53	35.21	2.80	-25.77	-2.05	34.08	2.71	-46.74	-3.72	-38.4	-3.05
Barren Land	1148.89	91.52	1190.56	94.83	1137.88	90.63	1165.39	92.82	41.67	3.32	-52.68	-4.19	27.51	2.19	16.5	1.31
Human Settle.	1.308	0.10	5.67	0.45	13.65	1.09	18.34	1.46	4.36	0.34	7.98	0.63	4.69	0.37	17.04	1.35
Scrub Land	27.01	2.15	5.54	0.44	1.12	0.09	15.34	1.22	-21.46	-1.70	-4.42	-0.35	14.22	1.13	-11.67	-0.92
Water Bodies	4.45	0.36	3.05	0.24	9.20	0.73	10.38	0.83	-1.40	-0.11	6.15	0.49	1.18	0.09	5.93	0.47
Mining	0	0	2.78	0.22	11.68	0.93	10.84	0.86	2.78	0.22	8.9	0.70	-0.84	-0.06	10.84	0.86
Hills	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub total	1255.31	100	1255.50		100	1255.50		100	1255.52		100	0	0	0	0	0000

Table 2. Area class distribution and land use land cover assessment of Jodhpur sites

Classes	Surface land area covered (km2)								Net area change (%)							
	1986		1996		2006		2018		1986-1996		1996-2006		2006-2018		1986-2018	
	Km2	%	Km2	%	Km2	%	Km2	%	Km2	%	Km2	%	Km2	%	Km2	%
Agricul. Land	2321.43	79.33	2337.43	79.88	2363.75	80.78	2110.88	71.13	16	0.54	26.32	0.89	-257.66	-8.80	-215.34	-7.35
Barren Land	158.79	5.43	206.05	7.04	277.06	9.47	282.07	9.63	47.25	1.61	71.01	2.42	5.10	0.17	123.37	4.21
Hills	110.09	3.76	143.49	4.90	134.46	4.59	94.19	3.21	33.39	1.14	-9.02	-0.30	-40.24	-1.37	-15.88	-0.54
Human settle.	36.90	1.26	51.24	2.02	55.91	1.70	121.32	4.15	22.31	0.76	-9.52	-0.32	71.64	2.44	84.44	2.88
Mining	15.68	0.54	71.86	2.98	35.91	1.23	98.26	3.86	71.39	2.43	-35.95	-1.22	76.94	2.62	97.17	3.32
Scrub land	229.72	7.85	76.33	2.61	25.51	0.87	200.61	6.86	-153.39	-5.24	-50.81	-1.73	175.16	5.98	-29.04	-0.99
Water Bodies	53.71	1.84	35.69	0.57	39.91	1.36	18.52	0.30	-37.09	-1.26	23.21	0.79	-31.09	-1.06	-44.82	-1.53
Sub total	2926.35	100.00	2926.30	100	2926.33	100	2926.26	100	0	0	0	0	0	0	0	0

Table 3. Area class distribution and land use land cover assessment of Barmer sites

Classes	Surface land area covered (km2)								Net area change (%)							
	1986		1996		2006		2018		1986-1996		1996-2006		2006-2018		1986-2018	
	Km2	%	Km2	%	Km2	%	Km2	%	Km2	%	Km2	%	Km2	%	Km2	%
Agricul.Land	97.00	7.72	292.55	23.29	509.85	40.58	864.49	68.81	195.55	15.52	217.3	17.30	354.63	28.23	767.49	61.10
Barren Land	883.75	70.35	675.85	53.80	471.73	37.55	102.54	8.16	-207.9	-16.55	-204.11	-16.25	-369.19	-29.39	-781.20	-62.19
Hills	211.03	16.80	223.71	17.81	212.13	16.89	216.27	17.22	12.65	1	-11.58	-0.92	4.14	0.33	5.21	0.41
Human Settle.	1.87	0.15	2.41	0.19	3.99	0.32	9.95	0.79	0.53	0.04	1.57	0.12	5.96	0.47	8.08	0.64
Mining	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0.0*
Scrub land	7.47	0.60	10.68	0.85	9.03	0.72	18.65	1.49	3.20	0.25	-1.64	-0.13	9.61	0.76	11.17	0.89
Water Bodies	55.04	4.38	51.08	4.07	49.56	3.95	44.32	3.53	-3.96	-0.31	-1.51	0.12	-5.23	-0.41	-10.71	-0.85
Sub total	1256.21	100	1256.30		100	1256.31	100	1256.31		100	0	0	0	0	0	000

*the value of mining is 0.003%, which is very less in comparison to an area of 1256.30 km2

Table-4: Class wise land use conversion of Jaisalmer site between 1986 to 2018

Class conversion between 1986 to 2018	Change (1986-2018) ha
Barren Land - Agricultural Land	2288.66
Barren Land - Human Settlement	1112.99
Barren Land – Mining	1035.39
Agricultural Land - Human Settlement	338.065
Agricultural Land – Mining	11.74
Agricultural Land - Barren Land	5484.25
Scrub Land - Human Settlement	379.85
Scrub Land – Mining	33.89

Jodhpur Site: For the LULC study, four permanent roosting sites were undertaken with a 20 km buffer. The buffer of all these sites overlapped each other, hence a single image was taken. In the Jodhpur site, major changes occur in the scrubland, agricultural land and barren land. Scrub land was converted into agricultural land (10879.90 ha), barren land (2363.18 ha.), Mining (1125.53 ha.) and human settlement (2810.34 ha.). Agricultural land was converted into the following classes i.e., barren land (19754.77 ha.), scrubland (11953.92 ha.), mining (4820.67 ha.) and Human settlement (3890.88 ha.). Barren land converted into agricultural land (6631.31 ha.), Human settlement (878.07 ha) and mining (2180.37 ha). Hills class converted into mining (351.80 ha.) and human settlement (1182.96 ha.) (Fig. 5, 6&7, Table 6.5).

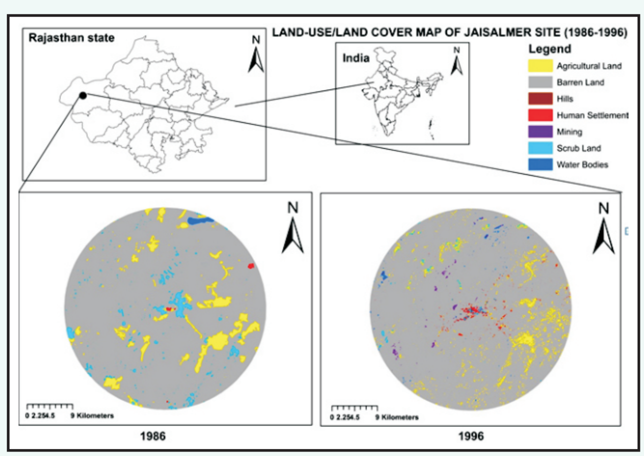

Figure-3: Land use land cover map of Jaisalmer site (1986-1996)

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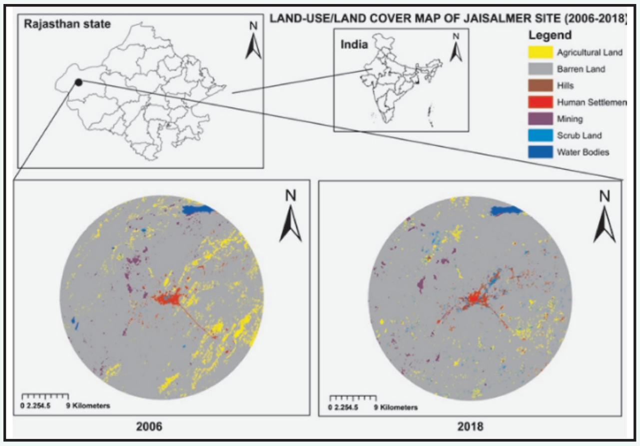

Figure-4: Land use land cover map of Jaisalmer site (2006-2018)

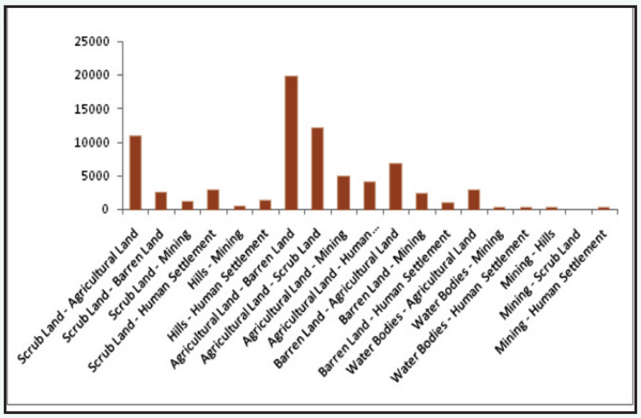

Figure-5: Change matrix and class conversion of Jodhpur sites from 1986-2018

Table-5. Class wise land use conversion of Jodhpur sites between 1986 to 2018

Class conversion between 1986 to 2018	Change (1986-2018) ha
Scrub Land - Agricultural Land	10879.90
Scrub Land - Barren Land	2363.19
Scrub Land – Mining	1125.54
Scrub Land - Human Settlement	2810.35
Hills – Mining	351.81
Hills - Human Settlement	1182.97
Agricultural Land - Barren Land	19754.78
Agricultural Land - Scrub Land	11953.92
Agricultural Land - Mining	4820.68
Agricultural Land - Human Settlement	3890.89
Barren Land - Agricultural Land	6631.32
Barren Land – Mining	2180.38
Barren Land - Human Settlement	878.09
Water Bodies - Agricultural Land	2748.89
Water Bodies – Mining	215.09
Water Bodies - Human Settlement	206.56
Mining - Scrub Land	40.49
Mining - Human Settlement	189.33

Barmer site: In the Barmer area, only one permanent roosting site and its surrounding of 20 km were taken as buffers to understand the land use change as bat habitats. The major change noticed was in the barren land class, 75132.14 ha. has been converted into agricultural land. This makes almost 66% of LULC change from one category to another (Fig.-8,.9& 10, Table-6).

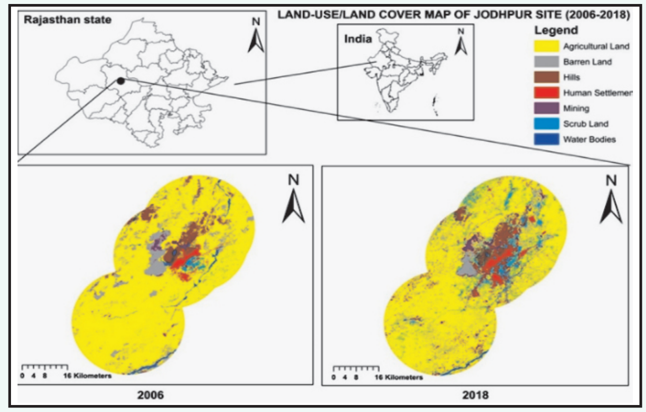

Figure-6: Land use land cover map of Jodhpur sites (1986-1996)

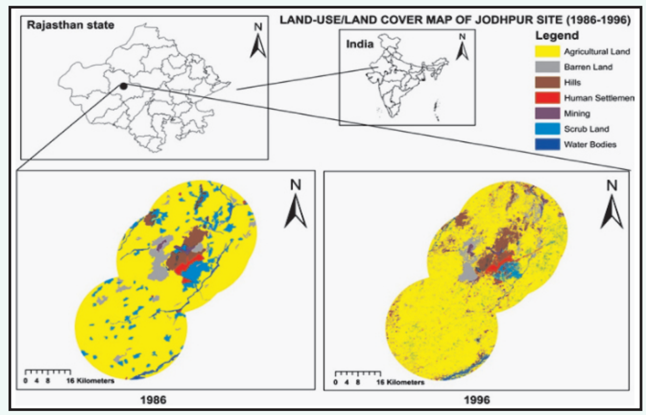

Figure-7: Land use land cover map of Jodhpur sites (2006-2018)

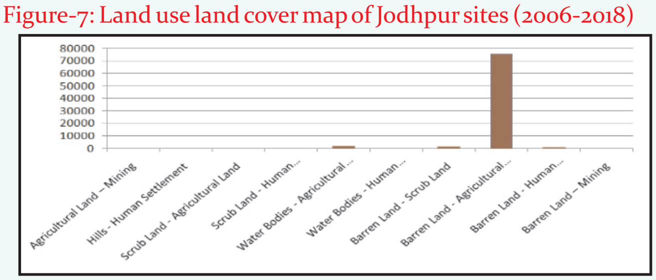

Figure-8: Change matrix and class conversion of Barmer site from 1986-2018

Table-6: Class-wise land use conversion of the Barmer site between 1986 to 2018

LULC(1986-2018)	Change (1986-2018) hr.
Agricultural Land – Mining	1.56
Hills - Human Settlement	47.33
Scrub Land - Agricultural Land	151.95
Scrub Land - Human Settlement	10.78
Water Bodies - Agricultural Land	1539.80
Water Bodies - Human Settlement	25.09
Barren Land - Scrub Land	1158.86
Barren Land - Agricultural Land	75132.15
Barren Land - Human Settlement	575.67
Barren Land – Mining	3.36

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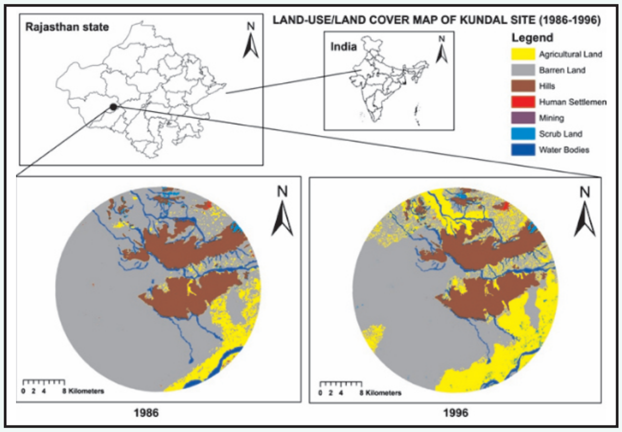

Figure-9: Land use land cover map of Barmer sites (1986-1996)

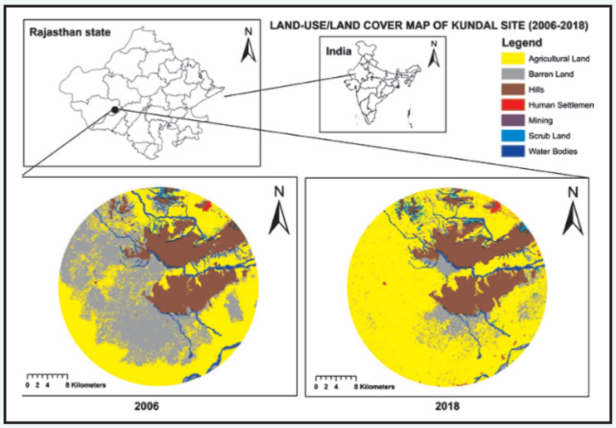

Figure-10: Land use land cover map of Barmer site (2006-2008)

Discussion

Many of the reasons affect the species diversity and population in particular landscapes. Land use changes are global threats to biodiversity. During the last fifty years, the economic development achieved by many countries it affected the global biodiversity and climate of earth. Bats are affected by this change and have changed their foraging range, diversity and species composition. Many studies have been conducted to investigate the current scenario. These studies were carried out by different – different characterizations like genic effect, behavioural responses, assemblage and population-level responses, and effect on the ecosystem service, habitat fragmentation, logging, forest, agroforestry system, plantation and agricultural (Meyer *et al.*, 2016). Bats are the response variable of the ecosystem health and environmental changes (Jones *et al.*, 2009). Bats are important pollinator and seed dispersal for tropical forest and also provides the essential insect pest (Muscarella & Fleming 2007; Kalka *et al.*, 2008; Williams-Guillén *et al.*, 2008; Kunz *et al.*, 2011; Maas *et al.*, 2013). Habitat fragmentation can vary from species to species, each species has a different home range but overall it can emphasise the stress between the species for food sharing. Three main factors influence the bats towards landscape fragmentation, i) fragmentation size in isolation landscape ii) landscape change with time (rate of change) iii) type and quality of matrix habitat (Meyer *et al.*, 2016). Species loss is clear evidence of fragmentation in certain time lags (Cosson *et al.*, 1999; Pons & Cosson 2002; Henry *et al.*, 2010). Several studies suggest that some tropical bats are more sensitive towards the edge effect (Meyer & Kalko 2008a; Klingbeil & Willig 2009, 2010; Henry *et al.*, 2010). Logging also affects the bat species richness and population in the landscape. In the last 40-50 years, deforestation has increased drastically, it changed biodiversity patterns immensely due to many species shifting to other forest patches or becoming extinct in the wild. The intensity of timber harvesting affects the rate of species composition (Clarke *et al.*, 2005a). Logging impact can be minimised through conservation efforts. The reservoir forest patches suppress the logging effect and maintain the population of sensitive species (Christine *et al.*, 2013). In the study, the Vietnamese karst forest suggests that Rhinolophidae and Hipposideridae were less abundant in logged forest compared to the primary original forest, (Furey *et al.*, 2010), which means habitat destruction and deforestation affects the bats' population and richness. These bats are more sensitive to habitat degradation. In the last 40 years, four species of bats are not been seen in this part of Thar Desert. During these decades, the species composition has been changed. Most of the insectivorous bats got affected which were more sensitive to land use change, they have been extinct locally. During the present study, a total of 272 roosting sites were surveyed in the study area.

Agriculture is the oldest practice for livelihood in the world. During ancient times, many crops were introduced for food and taste. For a meal, rice, corn and wheat is the most precious food items and they fulfil the demand of the world population.

Mono-cultural and poly-cultural agroforestry (coffee and cacao) support the frugivorous and insectivorous bats because of food availability (Castro-Luna & Galindo-González, 2012). But somehow it showed negative results for insectivorous bats which reduced foraging activity in the agroforestry system (Williams-Guillén & Perfecto, 2011). Isolating distance to the forest also impacts species richness (Estrada *et al.*, 1993a). Those landscapes cover more area in agroforestry and reduce the native forest as a result decreases the species richness (Faria *et al.*, 2006; 2007). High capture rates of Pteropodidae bats have been recorded in orchards of Borneo (Fukuda *et al.*, 2009). It means orchards support the fruit bats compared to ordinary forests and habitats and most bats have chosen the movement between the two habitat zones (Estrada *et al.*, 1993; Estrada & Coates-Estrada, 2002; Bianconi *et al.*, 2006; Medina *et al.*, 2007; Mendes *et al.*, 2009; Trevelin *et al.*, 2013). So it is important to conserve native forests and old habitats for species richness. It supports the bats' activity and provides the roosting spaces. To understand the planning of bat conservation we need to understand the use of land cover in particular landscapes.

Bats play an important role in the Thar Desert of Rajasthan, thousands of bats prey on millions of insects each and every day. It controls the overall insect population and contributes to the ecosystem. Many of roosting is full of bats guano; it gives nutrients and energy to invertebrates. This guano is rich in phosphorus, nitro compounds and other nutrients, which are essential for the farmers. Many farmers collected this black gold from the roosting sites. Overall bat community, supports the ecosystem as well as human livelihood. Thar Desert of Rajasthan is diverse in bat species, 16 species have been listed till now. In the last four decades, immense changes in bat diversity its a concern, due to urbanization and change in LULC pattern as it has two faces, both negative and positive. In the last four decades, three species have been missing which are *Megaderma lyra, Tadarida aegyptiaca* and *Pipistrellus dormeri* (*Scotozous dormeri*).

Hipposideros fulvus was re-sighted after 37 years (Dookia *et al*., 2017). All species have been reported in Jodhpur city and its suburb areas. But in the last four decades, *Megaderma lyra, Tadarida aegyptiaca* and *Pipistrellus dormeri* (*Scotozous dormeri*) have not reported.On the other hand, in the same time frame, human settlements and mining have increased by 84.44 km^2 and 97.17 km^2which is an immense change for a city. Mining destroys the old roosts and their habitat which affects the bats' diversity.

Interestingly, in the last forty years, two species have been added to the Thar Desert of Rajasthan *Cynopterus sphinx* (Dookia, 2003) and *Asellia tridens* (Senacha & Dookia, 2013). In the last four decades, agriculture pattern has changed, and new fruit orchards have been added. *Cynopterus sphinx* (Dookia, 2003) was sighted from the Jalore districts and Jalore and Barmer is the largest producer of pomegranate in Rajasthan state (Pagaria *et al.*, 2019). Extension of Agriculture or irrigation in new areas also influences the biodiversity of particular landscapes. Due to expand of the fruit orchards in the Thar Desert, the distribution of fruit bats also expanded simultaneously. Indian flying fox (*Pteropus medius*) has never been sighted in Jaisalmer districts in past, but during fieldwork first time sighted in Jaisalmer district and now a permanent colony is being established in the city. In the last ten years, Jaisalmer has introduced new fruit orchards, especially Date palm, as it is climatologically suitable for the date palm farming. These types of big fruit orchards attract the species of fruit bats. If agricultural practices are introduced in a sustainable way, it could be beneficial for the bats' diversity.

Some threats in the study area directly affect to bat population like wind energy farms, mining and diminished old buildings or roosting sites. Vast expenses of Thar Desert are good palace for wind farms, especially in Jaisalmer districts. Jaisalmer city vicinity area is surrounded by small to big windmills, which affects the bat population. During the study, Carcass of *Rhinopoma hardwickii* and *Taphozous perforatus* were found in the Jaisalmer area. In these areas, wind farms continuously works so a suggestion is that in the evening time, when bat emerges from their roosts at that time rotation of the blade should be stopped. Like evening bats (*Scotophilus* spp. and *Pipistrellus* spp.) come after 6 O'clock. At that time, the mortality of bats had increased and bat reflectors should be installed in each wind turbine over the head of windmills. Mining is also a bigger threat the bat diversity, as rock mining destroys the roost and roosting habitat of bats. Bats roost in caves and crevices of rock or hills. Some bat chooses the hills or rock for roosts like *Hipposideros fulvus* and *Tadarida aegyptiaca*. These natural roosts are important for bat diversity and important for species which are dependent on the natural roosts. If natural roosts are diminished then it affects the bat's diversity and its population.

Old buildings are also important for the Bats diversity like *Rhinopoma hardwickii* and *Rhinopoma microphyllum*, both species were selected for the maximum man-made structures like old houses and old wells which are situated in the Urban and Rural areas. Old wells are very important for both species; the largest number of roosting sites are old wells. It supports the biggest population of bats. In a single well, thousands of bats can roost for example one well is situated in the vicinity of Mehrangarh Fort in Jodhpur, where thousands of bats (*R. hardwickii* and *R. microphyllum*) were spotted. Wells provides suitable environmental conditions for bat species so they can survive. Old buildings also provided shelter to the bats, especially in small towns huge number of bats with human habitation. Nowadays, people renew the old buildings into new one and destroys the roosts of bat species. This is also a major threat to bats which affects the bat population as well as diversity.

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