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Vulnerability of Different Geomorphic Units to Deserts in Parts of Western Rajasthan - A Study Based on Remote Sensing and GIS

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Abstract

Deserts are the areas of arid ecosystem which make vegetal and animal life difficult to sustain. The process which makes desert is called desertification. It also faces the loss of fertile topsoil at desert boundaries and usually caused by a combination of drought and the over exploitation of grasses and other vegetation by people. Desert sand dunes being soft, are more prone to erosion whether wind or water. Earth Observation Technology (EOT) by use of multi-sensor polar orbiting satellites is able to provide fairly good mapping and monitoring of deserts. An attempt to explore the potential of EOT in studying desertification nexus with geomorphic units in the area of Thar desert of Rajasthan, India has done.

Keywords: Deserts; Vulnerability; GIS; Remote sensing; Western Rajasthan

Introduction

Cultivable land is the valuable natural resource which supports production food and fiber and many other essential goods required to meet human and animal needs for sustenance. However, it is facing serious threats of deterioration due to unrelenting human pressure and utilization incompatible with its capacity. Situation becomes more serious for the nation like India, where to cop up with agriculture production demand, large fertile land is required. A serious threat to this is desertification. Katyal and Vlek describes desertification is a condition of human-induced land degradation that occurs in arid, semiarid and dry sub-humid regions (P/PET 0.05 to 0.65) and leads to a persistent decline in economic productivity (>15% of the potential) of useful biota related to a land use or a production system [1-3]. Climatic variations intensify the decline in productivity, restorative management moderates it. Some of the main human and biotic interactions that are causing desertification hazards in the area are:

- Uneconomic land use/cultivation practice on the sand dunes, marginal lands affecting adjacent fertile lands area a means to soil erosion.
- The intensive use of water resources or it's over exploitation leading to rise in water tables, seepage and increased salinity.

The EOT has been proven of immense help in mapping, monitoring and studying change detection of desert areas due to its capacity to cover larger area, temporal data availability, affordable cost and accuracy [4-6]. The present study focuses on delineation of major geomorphic features of the area, vulnerable geomorphic processes characterization and identification and GIS analysis for vulnerable classes of desertification.

Study Area

The study area is composed of six blocks namely Ahore, Luni, Pachpadra, Pali, Rohat and Siwana of four districts Jodhpur, Pali, Barmer and Jalore of Rajasthan state. In the local language area is known as Marusthali (desertic). It is located between 25°15'N to 26°20'N latitudes and 72°E to 73°40'E longitudes. The total geographical area is 1183984.18 hectare. The area is covered in 30 toposheets prepared by survey of India on the scale of 1:50000.

Climate

The area falls under arid agro-climatic condition in Thar Desert of Rajasthan with four seasons *viz*., winter, summer, monsoon, and post monsoon. The climate of the region is hot and dry. Rainfall received is very less, the temperature is very high all around the year and all these conditions generate an arid to semi-arid picture of the area. The temperature variations are also great.

The temperature begins to rise from the month of March and May reach up to 50C occasionally particularly in the Barmer district during the June and July. High temperature may be associated with high-speed dust storms, which are normal in the month of April and May. Even in the winter season also the daytime remains quite hot. The received sunshine per day is around 9 hours. This can be given as the reason of high temperature because when sunrays fall on the sand it become hot and raise the surrounding temperature. The mean maximum summer temperatures (may) range from 40°C to 42°C. During winter (December to February) the mean maximum temperature ranges from 15°C to 25°C and the minimum temperature slash down to the freezing point. The average annual rainfall received in the area is about 278.78 mm (Figure 1).

Spatial Distribution of Land Use/Land Cover

Land use and land cover of the study area is done with ETM 2000 of LANDSAT Satellite data and IRS LISS-III 2006 of all the three-season data *viz*., Kharif, Rabi and Zaid (Table 1). The classification scheme adopted for present study includes six classes at level-I and twenty-two classes at level-II. On the basis of land use and land cover area can be broadly classified as agriculture land, built up land, forested land, waste lands and water bodies as per level-1 land use\land cover classification system developed by NRSA. During 2000, about 32.45% area was under fallow land followed by 20.09%, 3.95%, 3.15%, 33.02% area under crop,

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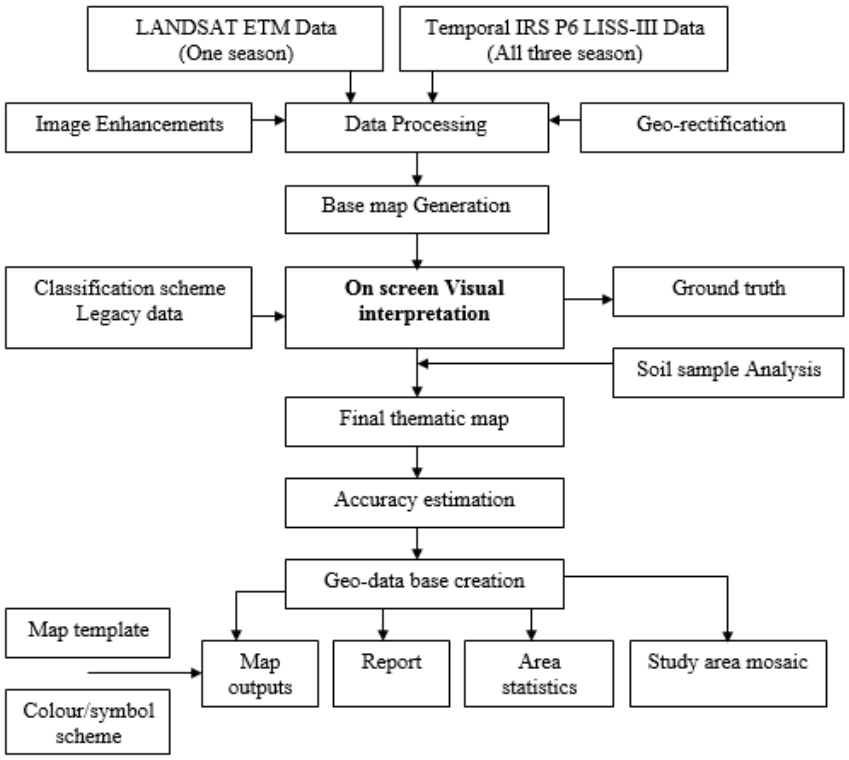

Figure 1: Schematic of Methodology Adopted.

LULC: Level – I	LULC: Level-II	Area (ha)	% of Study Area
Built-up	Urban settlement	2120.05	0.18
	Rural settlement	6423.52	0.54
Agriculture	Only Kharif	237872.15	20.09
	Fallow land	384148.02	32.45
Forest	Dense Forest	468.18	0.04
	Reserved Forest	1554.79	0.13
Wasteland	Land with scrub	46755.62	3.95
	Land without scrub	37328.88	3.15
	Sandy Desertic	390927.18	33.02
	River Sand	23308.10	1.97
	Barren Rocky	37064.43	3.13
	Salt waste	5643.53	0.48
Water bodies	River with water	717.24	0.06
	Canal	309.14	0.03
	Ponds	3069.93	0.26
Salt Basin	Salt basin	6273.41	0.53
	Total	1183984.17	100.00

Table 1: Landuse/Landover Categories in Year - 2000.

land with scrub, land without scrub and sandy desertic (Figure 2). The forest area is very less.

During 2005-2006, the areas under various land use/land cover categories changed considerably (Table 2). About 32.42% of total area was under fallow land followed by 9.92%, 4.75%, 0.66%, 3.33%, 0.22%, 0.53%, and 0.70% area under only kharif, only rabi, only summer, kharif and rabi, kharif and summer, rabi and summer and all the three kharif, rabi and summer [7,8].

An assessment of change in area under various land use/land cover categories during 1999-2000 to 2005-2006 revealed that agriculture area increased by 263.25 ha. The wastelands decreased by 136.17 ha because the decrease noticed in the sandy desertic and due to various reclamation measures taken by farmers. However, there is marginal decrease (9.08) in surface water resources (Figure 3).

Results and Discussion

Land degradation assessment

The increasing human and livestock population pressure over

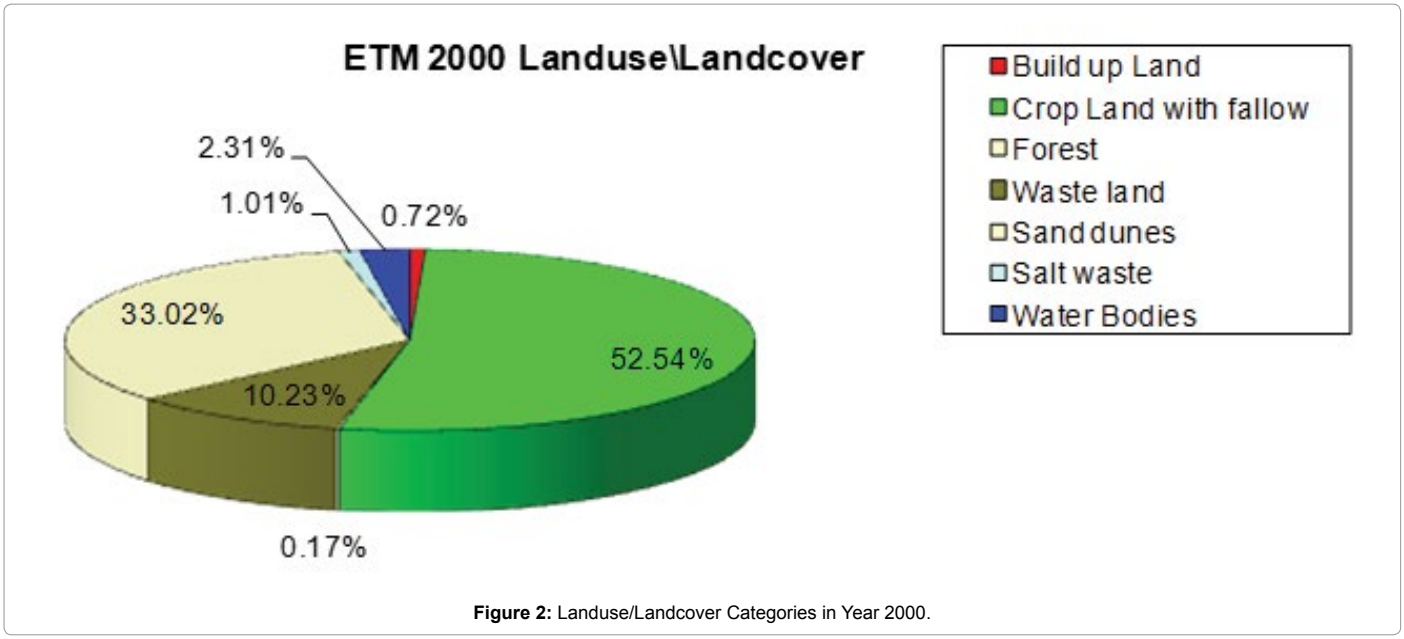

Figure 2: Landuse/Landcover Categories in Year 2000.

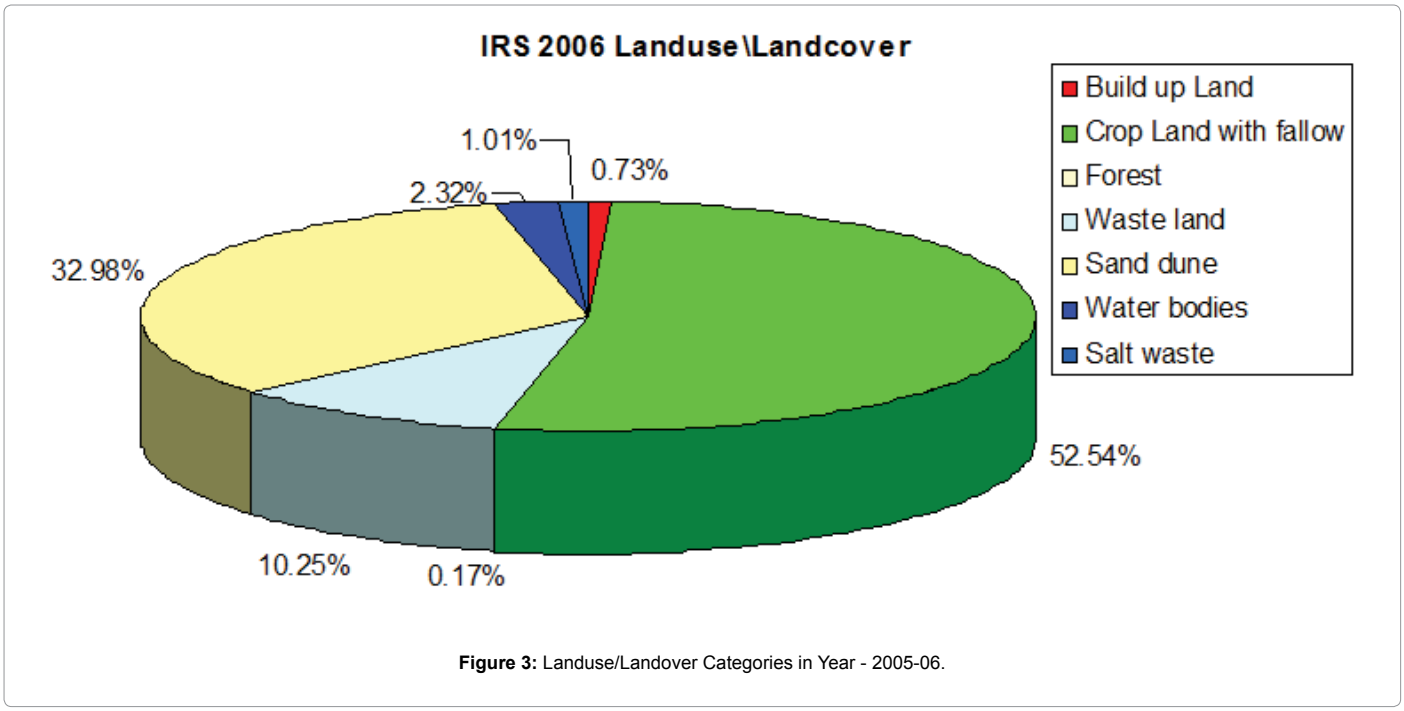

Figure 3: Landuse/Landover Categories in Year - 2005-06.

the last decade has disturbed the ecological balance of study area to a considerable extent. As a result, many areas have converted into degraded land. The severity classes find in the area are identified *viz*., slight, moderate and severe for all wind, water and salinization processes (as per NRC Land Degradation Manual). The major processes of degradation active in the study area are wind erosion, water erosion and salinization. As it falls in the desert, the wind erosion is much more prone then other categories. Area affected by wind erosion process (slight) covers 1.23% of Ahore block, followed by 2.42% in Siwana, 12.27% in Pachpadra and 10.97% in the luni area respectively.

About 3692.30 ha (1.76%) of Siwana, 10937.55 ha of luni (5.66%) and 7171.63 ha (2.08%) area of Pachpadra blocks, respectively are degraded by wind erosion process with moderate severity. The area affected by wind erosion severe is 951.65 ha (0.59%) in the ahore block, 4586.26 ha (2.19%) in Siwana block, 7916.08 ha (2.30%) in Pachpadra block, 6901.61 ha (3.57%) in luni block, 3256.81 ha (2.49%) in Pali block and 2709.28 ha (1.91%) in the Rohat block. Wind erosion process, in general, affected both agricultural and wastelands. The sandy patches may be *in situ* or transported in origin. Windblown sand dunes support vegetation where moisture available. Water erosion process (severe i.e., formation of ravines) was more predominant in ahore block where

LULC: Level – I	LULC: Level-II	Total Area (ha)	% of Total Study Area
Built –up	Urban settlement	2206.39	0.19
	Rural settlement	6439.03	0.54
Agriculture	Only Kharif	117440.70	9.92
	Only Rabi	56198.02	4.75
	Only Summer	7811.77	0.66
	Kharif- Rabi	39392.99	3.33
	Kharif- Summer	2643.21	0.22
	Rabi-Summer	6313.08	0.53
	Kharif- Rabi-Summer	8336.04	0.70
	Fallow	383905.15	32.42
Forest	Dense Forest	466.44	0.04
	Reserved Forest	1560.04	0.13
Wasteland	Land with scrub	46915.00	3.96
	Land without scrub	37423.35	3.16
	Sandy Desertic	390533.24	32.98
	River Sand	23318.44	1.97
	Barren Rocky	37044.75	3.13
	Salt waste	5656.79	0.48
Waterbodies	River	725.48	0.06
	Canal	309.02	0.03
	Ponds	3070.89	0.26
Salt basin	Salt basin	6274.37	0.53
	Total	1183984.17	100.00

Table 2: Landuse/Landover Categories in Year - 2005-06.

4.24% of block area is degraded by it, followed by 2.58%, 2.32%, 2.30%, 2.19% and 1.02% areas under Pali, Rohat, Pachpadra, Siwana and Luni blocks respectively. Water erosion is a major process of land degradation both in arable and non-arable lands. However, ravine formation is generally observed in barren lands along river or drainage network due to high intensity rainfall and subsequent rapid runoff. In some of the blocks the moderate and slight water erosion is also observed (Table 3).

Salinization process (moderate) affected only one or two blocks small area (22413.06 ha) of Pachpadra block, which is 6.52% of the block area and 0.87% (1683.74 ha) area of the luni block. In the part of Siwana slight salinization is also noticed which is 2.17%. Salinization process is active mostly in unirrigated agricultural land and scrublands. Salinity development has been taken place due to inherent limitation or brackish groundwater and its subsequent capillary rise to the surface in the part of Pali and Ahore blocks. In the Pachpadra block one salt basin is also present that is known as Pachpadra salt basin. It covers the total area of 6275.45 ha of the block (1.82%).

Change analysis

Changes in land use/land cover pattern during 1999-2000 to 2005-2006 are evaluated (Table 4). Although the change is not that much varied. Changes in the directions namely degraded wasteland categories to cropland, water bodies and plantation etc., has been considered as 'positive change'. About 1032.02 ha have been improved because of 'positive change'. Changes in the reverse direction namely, fallow land to wastelands; forest to wastelands; dry water bodies to wastelands etc. have been considered as 'negative change'. Area degraded due to negative changes covers about 279.31 ha which is almost negligible (Table 5). Parts of the remaining area have undergone changes but those can't be regarded either positive or negative. About 11832672.84 ha belong to 'no change' category (Figure 4).

Vulnerability of geomorphic units

The vulnerability of different geomorphic units on the basis of weathering resistant capacity (bearing capacity), water erosion severity, wind erosion severity, vulnerable water erosion classes, vulnerable wind erosion classes with other collateral data like soil erosion, slope etc. is prepared. The classes *viz*., high, moderate and low are made on this basis. This table shows that dune field, aeolian plain, valley fills, flood plain and piedmont slope aeolian show the high vulnerability to the land degradation and desertification in the particular area of Thar desert. All the geomorphic units consist of igneous rocks shows low to moderate category because of hard and compact nature of the rock and high resistance capacity like-pediment volcanic, pediment granite etc. The geomorphic units like pediment volcanic, denudational hill volcanic show the low category because of their hard and compact nature.

Table 6 also shows the reverse relationship between bearing capacity of the rock and vulnerability level. The softer the geomorphic unit, greater the activeness of the erosion activity in the case of wind. In the case of water, it depends upon the chemical reaction. According to the table dune field having the low bearing capacity and thus the vulnerability level is high. In the case of denudational hill volcanic bearing capacity is moderate to good but the vulnerability level is low.

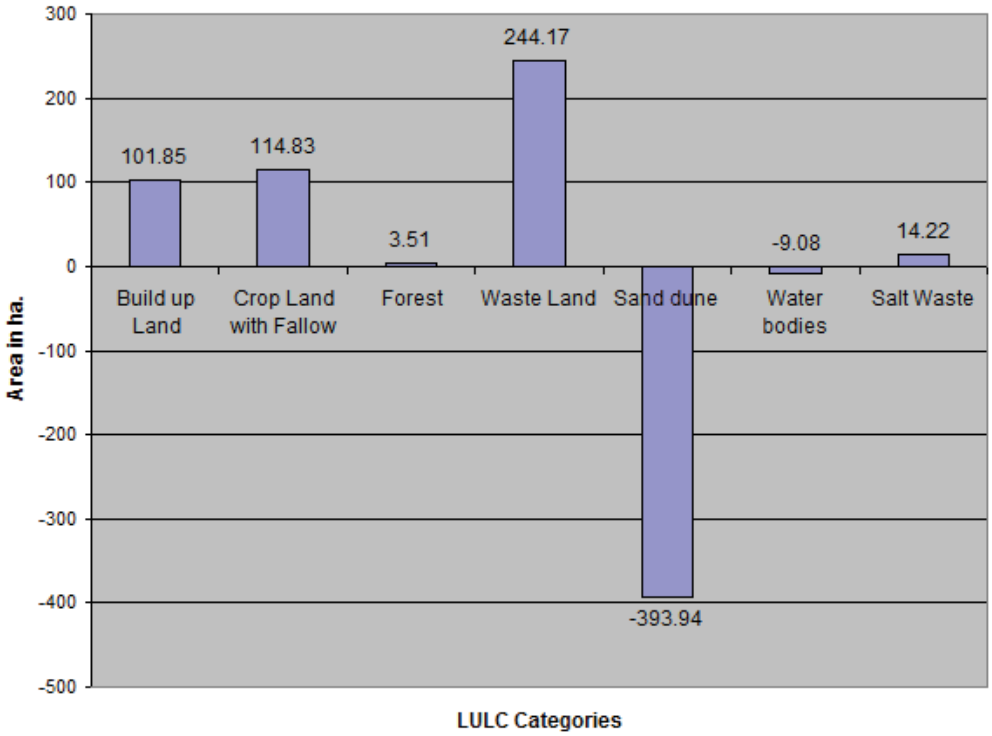

Figure 4: LULC Categories change during 2000 to 2005-06.

Block Name	Process of Degradation-Severity	Area (ha)	% of Corresponding Block Area
Ahore	Wind erosion-Slight	2015.46	1.23
	Wind erosion-Severe	951.65	0.59
	Water erosion-Slight	8551.24	5.22
	Water erosion-Severe	6948.65	4.24
Siwana	Wind erosion-Slight	5079.60	2.42
	Wind erosion-Moderate	3692.30	1.76
	Wind erosion-Severe	4586.26	2.19
	Water erosion-Slight	2978.34	1.42
	Water erosion-Moderate	11283.62	5.38
	Water erosion-Severe	3897.59	1.86
	Salinization-Slight	4562.0	2.17
Pachpadra	Wind erosion-Slight	42211.10	12.27
	Wind erosion-Moderate	7171.63	2.08
	Wind erosion-Severe	7916.08	2.30
	Water erosion-Slight	4206.38	1.22
	Water erosion-Severe	8594.55	2.49
	Salt Basin	6275.45	1.82
	Salinization-Moderate	22413.06	6.52
Luni	Wind erosion-Slight	21201.88	10.97
	Wind erosion-Moderate	10937.55	5.66
	Wind erosion-Severe	6901.61	3.57
	Water erosion-Moderate	1120.36	0.57
	Water erosion-Severe	1979.92	1.02
	Salinization-Moderate	1683.74	0.87
Pali	Wind erosion-Severe	3256.81	2.49
	Water erosion-Slight	4569.21	3.48
	Water erosion-Severe	3386.81	2.58
Rohat	Wind erosion-Severe	2709.28	1.91
	Water erosion-Moderate	1936.09	1.36
	Water erosion-Severe	3302.94	2.32

Table 3: Area affected by various degraded processes in different blocks.

LULC: Level – I	LULC: Level-II	Total area based on Landsat data (ha)	Total area based on IRS LISS – III data (ha)	Change in Area (ha)
Built –up	Urban settlement	2120.05	2206.39	81.95
	Rural settlement	6423.52	6439.03	15.51
	Sub total	**8543.57**	**8645.82**	**101.85**
Agriculture	Only Kharif	237872.15	117440.70	263.65
	Only Rabi		56198.02	
	Only Summer		7811.77	
	Kharif- Rabi		39392.99	
	Kharif- Summer		2643.21	
	Rabi-Summer		6313.08	
	Kharif- Rabi-Summer		8336.04	
	Fallow	384148.02	383905.15	-242.84
	Sub total	**622020.17**	**622160.95**	**20.81**
Forest	Dense Forest	468.18	466.44	-1.74
	Reserved Forest	1554.79	1560.04	5.25
	Sub total	**2022.97**	**2026.48**	**3.51**
Wasteland	Land with scrub	46755.62	46915.00	159.38
	Land without scrub	37328.88	37423.35	94.47
	Sandy Desertic	390927.18	390533.24	-393.94
	River Sand	23308.10	23318.44	10.34
	Barren rocky	37064.43	37044.75	-19.68
	Salt waste	5643.53	5656.79	13.26
	Sub total	**541027.74**	**540891.57**	**-136.17**
Waterbodies	River	717.24	725.48	8.24
	Canal	309.14	309.02	-0.12
	Ponds	3069.93	3070.89	0.96
	Sub total	**4096.31**	**4105.39**	**-9.08**
Salt basin	Salt basin	6273.41	6274.37	0.96
	Total	1183984.17	1183984.17	

Table 4: Change in area under various land use/land cover categories during 00 to 05-06.

Change Type	Area (ha)
Positive change	1032.02
Negative change	279.31
No change	1182672.84
Total	**1183984.17**

Table 5: Type of changes in land use/land cover during 2000 to 2005-06.

S. No.	Geomorphic Unit	Erosion Resistant Capacity	Vulnerability Level
1.	Dune Field	Low	High
2.	Pediplain	Low	Moderate
3.	Eolian Plain	Low	High
4.	Denudational Hill	Moderate	Moderate
5.	Pediment Volcanic	Moderate to good	Low
6.	Denudational Hill Sedimentary	Moderate	Low
7.	Denudational Hill Volcanic	Moderate to good	Low
8.	Pediplain Granite	Moderate to good	Low
9.	Pediment Sedimentary	Moderate	Moderate
10.	Valley Fills	Low	High
11.	Residual Hill	Moderate	Moderate
12.	Pediplain Granite	Moderate	Moderate

13.	Playa	Low to moderate	Moderate
14.	Undulating Plain	Low	High
15.	Under Fill	Low	High
16.	Flood Plain	Low to moderate	High
17.	Inselberg	Moderate	Moderate
18.	Pediplain Phyllite	Low to moderate	Moderate
19.	Sandy Plain	Low	High
20.	Pediment Granite	Moderate to very good	Low
21.	Denudational Hill Granite	Moderate	Low
22.	Pediment	Moderate	Moderate
23.	Burried Plain	Moderate	Moderate
24.	Peidmont Slope Eolian	Low to moderate	High
25.	Lineament	Moderate	Moderate

Table 6: Relationship between bearing capacity of the rock and vulnerability level.

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