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Desertification monitoring in Sojat taluka, Pali district, Rajasthan using satellite data

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Abstract: Desertification is the process of land degradation occurring in arid, semi-arid and dry sub-humid areas of the world leading to transformation of productive land into a desert, affecting living conditions of billions of people. In India, about one third of its geographic area is undergoing the process of land degradation. For making mitigation plan to combat desertification, inventory and monitoring of the undergoing process of desertification and severity are the primary requirement. Objective of the present paper is, therefore, to monitor desertification status which provides information on the spatial extent of the area under desertification, its type and severity over 25 years. Multi-season Landsat TM data of 30 m spatial resolution, pertaining to the years 1991, 2000 and 2017, have been analysed to prepare desertification status map (DSM) on 1: 25,000 scale for parts of Pali district, Rajasthan state in western India. Monitoring and assessment of the desertification has been carried out for a period of 25 years. DSM has also been prepared on 1: 10,000 scale using very high spatial resolution data of Resourcesat-2 LISS-IV to implement desertification combating plans on the ground.

Keywords: Desertification, Land degradation, Satellite data, Desertification Status Mapping (DSM)

1. Introduction

Land degradation/desertification is one of the most pressing environmental concerns all over the world (UNCCD, 1994; 2001). Land degradation refers to reduction or loss of the biological or economic productivity, resulting from a combination processes arising from human activities and habitation patterns (UN, 1994). Land degradation in drylands is called as desertification. Desertification is a process whereas ‘desert’ is the state of land and its environment. Desertification process, if not controlled, may transform a productive land into ‘desert’ or degraded/waste land. Arid, semi-arid and dry sub-humid lands are called dry lands. Many ecological features such as limited water resources, rainfall variability, thin plant cover and low organic matter content disturbs the fragility of dry lands. Over one billion people in more than hundred countries are at risk because of desertification (Adger et al., 2000). Impact of desertification on ecological processes are many and complicated, including negative changes in vegetation properties (such as biomass, density, vegetation cover), loss of biodiversity and soil fertility and changes in landscape patterns over dry regions at different geographical scale (Xu et al., 2009; Thornes and Brandt, 1996). In broader sense, desertification may lead to complete failure of balance between demand and supply of ecosystem services in drylands (Biro et al., 2013).

India supports about 16.2 percent of the world’s human population though it occupies only 2.4 percent of world’s geographical area. It has only 0.5 percent of the world’s grazing area but supports 18 percent of the world’s cattle population. Increasing population (human and cattle) pressure is responsible for disturbing the fragile ecosystem and applies excessive pressure on natural resources of our country. About 228 mha (70%) of its geographical area falls within the drylands (arid, semi-arid and dry sub-humid) which is extremely vulnerable to over-exploitation and inappropriate land use. A very large area of the country is affected by land degradation or desertification due to its physiography, topography, extreme weather conditions and natural disasters. Further, anthropogenic activities like deforestation, shifting cultivation, overgrazing, unsustainable agricultural practices, cultivation in marginal lands and steep slope areas, industrialization/urbanization and mining have been the major cause of land degradation and desertification. Socio-economic condition of the people is also the major cause of desertification and land degradation. Spatial information on the land undergoing desertification, in terms of its spatial extent, the type and severity of processes of land degradation, is prerequisite for formulation of strategies to mitigate and rehabilitate the menace of land degradation and desertification in order to enhance food production and to restore the fragile ecosystem.

Field based survey and remote sensing are suggested methods for studying land degradation and desertification. Advantages of using remote sensing technology include its synoptic view, cost-effective, real-time data acquisition, wide and repetitive coverage, are faster than ground methods and facilitate long term monitoring (Albed and Kumar, 2013). Extensive research using satellite imagery along with GIS have been conducted for mapping and monitoring land degradation/ desertification, mostly with multispectral sensors including Landsat data series and the Indian remote sensing (IRS) series of satellites (LISS-III and AWiFS) (Dwivedi, 2001; Verma et al., 1994; Ajai et al., 2007; 2009; Dhinwa et al., 2013; 2016; SAC, 2016). One of the basic requirements for making the mitigation plan to combat desertification is inventory of the land undergoing the process of degradation, the type of processes and their severity. In India, three levels classification system (land use classes, land degradation processes and severity levels) have been standardized and used for mapping of land degradation and desertification at national and district level (Ajai 2009; SAC, 2016). However, land degradation/desertification mapping at larger scale is required for developing action plans for combating land degradation/desertification.

The present study deals with the mapping and monitoring of land degradation and desertification on 1:25,000 scale in the Sojat taluka of Pali district falling in the arid regions of the Rajasthan state. Monitoring of desertification through time is very important to know if there is any impact of the implementation of the actions towards combating the desertification. It is also important to study and understand if the land degradation (intensity in terms of area and severity) is increasing or decreasing with time. This helps in making an appropriate strategy to arrest the processes of land degradation. Thus the present study was carried out to assess the desertification in terms of its extent and severity, using satellite data for the Sojat taluka of Rajasthan over a period of 25 years. Detailed level mapping of desertification, extent, type and severity has also been carried out on 1: 10,000 scale using IRS – LISS IV data having 5.8 m spatial resolution. Spatial information from this large scale DSM map along with the information on topography and morphology, inferred from Cartosat-1 image (2.5 m spatial resolution panchromatic stereo), can be used to suggest locale specific actions for combating desertification.

2. Materials and methods

2.1 Study area

Sojat taluka, Pali district, Rajasthan is located at 25° 92 N, 73° 67' E covering an area of 1,965,25 hectares. Sojat is bounded by Jodhpur district in the north-eastern, Pali in the south-western, Marwar junction in the south-eastern and Raipur towards the north-western side. It has Sukri river and Lilri Nadi as the major rivers flowing through the taluka. The whole region lies on the way of Aravalli hills range. The area receives a mean annual precipitation of 470 mm. The temperature of the taluka ranges from 20° C in winters to 35° C in summers (Jamal et al., 2016).

About, 40-50 per cent area of the taluka is covered with coarse loamy (moderate to deep) soils. Apart from this, the skeletal loamy soil can be found in the regions where dissected mountains and scrublands are present. The land is characterized by limestone rocks and deposits. The limestone deposit near Mandla-Atbara is a part of the main limestone belt stretching over a length of 160 km and 0.80 to 12 km wide. This belt comprises mainly cement grade having intercalation of cherty and siliceous limestone in the form of intermittent bands. This has made its way for extensive quarrying and mining in the area. Water erosion, wind erosion, vegetal degradation is amongst the natural desertification processes observed. Sojat is also called the Henna city or the Mehandi nagri. It is India's largest henna cultivating and producing town. On the eastern side of Aravalli range, a sparse forest can be seen. Thus, grasses and thorny shrubs for the dominant vegetation. The most prolific vegetation seen in this state is Prosopis cineraria, Babul (Acacia nilotica), peepal (Ficus religiosa), and banyan (Ficus benghalensis) amongst others. Demographically, Sojat, there are 124 villages and 12,472 households in the region with a total population of 220,584 people.

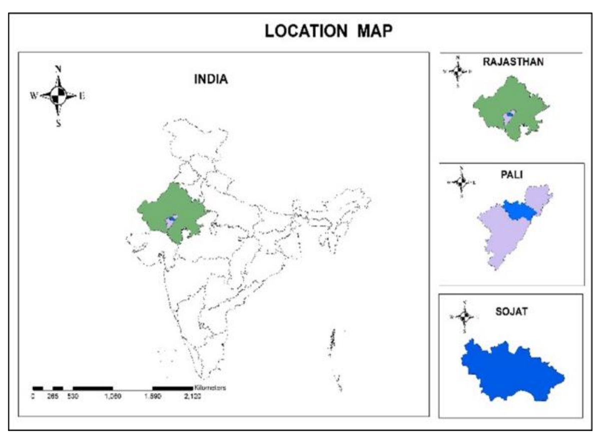

Figure 1: Location map of the study area

2.2 Data used

To prepare desertification status map for Sojat taluka, Pali district (Rajasthan, India), Landsat data coming from three different sensors (TM-Thematic Mapper; ETM+- Enhanced Thematic Mapper and OLI-Operational Land Imager), Resourcesat II LISS IV data, ancillary information and collateral data have been used. The details of the data are given in Table - 1. Landsat multi-temporal data have been used to monitor the desertification status in the study area over 25 years. For each selected year multi-seasonal (Rabi, Summer and Kharif) Landsat datasets have been used to map the land-use, degradation processes and severity. Landsat TM (1991), Landsat ETM+ (2000) and Landsat OLI (2017) provided by Global Land Cover Facility Programme (http://glcfapp.umiacs.umd.edu) and United States Geological

Survey (USGS) Earth explorer programme and was freely downloaded from http://www.usgs.glovis.gov. LISS IV Resourcesat II (2016) high spatial resolution satellite data was ordered and procured from National Remote Sensing Centre (NRSC) (website) for thematic mapping.

Table 1: Data used for the study

	Data used	**Spatial resolution**	**Date of acquisition**
Satellite data	Landsat 4-5	30m	23-1-1991
	Landsat 7	30m	24-01-2000; 15-05-2000; 20-09-2000
	Landsat 8 (OLI)	30m	05-01-2017
	IRS-LISS IV	5.8m	12-01-2016; 05-02-2016
Ancillary data **SOI Topographical maps** **(1:50,000)**	45K/1, 45F/6, 45F/8, 45F/12, 45G/5, 45G/6, 45G/9, 45G/10	--	--

3. Methodology

Survey of India (SOI) topographical maps (Table 1) pertaining to, Sojat taluka, Pali district (Rajasthan, India) at the scale of 1: 50,000, were used to demarcate and delineate taluka boundary and for preparation of base map. Base map was prepared using relevant information on major water bodies, settlements, drainage network, major road and rail network from the SOI maps (Fig. 1). SOI maps were also used to extract the Ground Control Points (GCPs) and then used for image geo-referencing and co-registration of multi date Landsat data (TM, ETM+ and OLI) and Resource-sat II LISS IV using ERDAS Imaging 2015. Desertification Status Maps (DSM) have been prepared on 1:25,000 scale using multi-season Landsat data. National level standardized classification system for DSM has been followed (Ajai et al., 2007). Cartosat-1 and IRS LISS-IV imageries were also used as supporting data, mainly as an aid to analyst. Detailed steps followed in preparation of DSM are given in Fig. 2. Landsat data coming from three different years 1991 (TM); 2000 (ETM+) and 2017 (OLI) have been used to monitor the changes in the land degradation/desertification status over 25 years on 1:25,000 scale. The classification system used to map various processes and their severity is given in table 2. Multi-temporal and multi-seasonal satellite data were interpreted using visual analysis and on-screen digitization techniques, to prepare DSM for the study area. Photographic elements such as tone, texture, size, shape, pattern, association were considered for delineating the land-use classes, land degradation processes (types) and severity. ERDAS imagine 2015 and Arc GIS 10.4 were used for digital image processing and GIS analysis respectively. DSM maps were prepared on 1: 25,000 using Landsat using ArcGIS 10.4. IRS-LISS IV data of 2016 have been used to prepare DSM of Sojat taluka on 1: 10,000 scale. This map will be useful in preparation of action plans for combating desertification, at cadastral level. Change detection in DSM maps were computed using Landsat data series (TM, ETM+, OLI) for the years of 1991, 2000 and 2017, in hectares as well as in percentage.

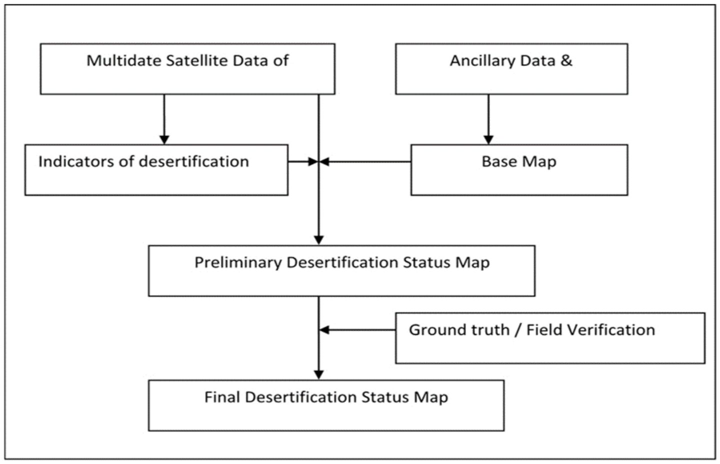

Figure 2: Methodology for preparation of desertification status map

Table 2: National standardized classification system for desertification status mapping (Source Ajai et al., 2007)

Class	Symbol
Level:1 Landuse/Landcover	
Agriculture – unirrigated	D
Agriculture – irrigated	I
Forest/plantations	F
Grassland/grazing land	G
Land with scrub	S
Barren/rocky area	B/R
Dune/sandy area	E
Water body/drainage	W
Glacial/peri-glacial (in cold region)	C/L
Others (urban, man-made etc.)	T
Level:2 Processes of degradation	
Vegetal degradation	v
Water erosion	w
Wind erosion	e
Water logging	l
Salinization/alkalinisation	s/a
Mass movement (in cold areas)	g
Frost heaving (in cold areas)	h
Frost shattering (in cold areas)	f
Manmade (mining/quarrying, brick kiln, industrial effluents, city waste, urban, etc.)	m
Level: 3 Severity of degradation	
Severity	**Level**
Low	1
Moderate	2
High	3

4. Results and discussion

Desertification status map (DSM) of Sojat taluka, Pali district (Rajasthan, India) have been prepared on a scale of 1:25,000 scale using Landsat data, for the years of 1991 (TM); 2000 (ETM+) and 2017 (OLI) and ancillary information following the methodology as given in fig. 2. These maps are presented in figure 3. The above DSM maps show spatial distribution of land degradation processes along with severity.

Sojat taluka has a total geographical area of 196525 ha. Figure 3 (A – C) show DSM prepared at 1:25000 scale for the year 1991, 2000 and 2017, respectively. It reveals that vegetal degradation, wind erosion, salinity, water erosion and man-made (mining/quarrying) are the significant processes of land degradation observed in the prepared DSM using Landsat data. DSM maps shows that the total land area undergoing process of degradation are 36700 ha in 1991, 34731 ha in 2000 and 32837 ha in 2017, which are 18.6%, 17.6%, and 16.7% respectively of the total geographical area mapped (TGA) of the study area. Vegetal degradation (in scrub land and forest), salinity and water erosion were the major desertification processes across the selected time frame from 1991 to 2017.

Vegetal degradation is the major contributor of land degradation in the study are over 25 years. Prosopis juliflora (sw.) DC and Acacia nilotica (L.) WILLD EX DEL. are the main vegetation found in the scrub land in the study area. Mixed vegetation was observed in the forested areas of Aravalli range. Vegetal degradation in scrublands and forest have been mapped into three severity classes: low severity (Sv1), moderate severity (Sv2) and high severity (Sv3). The criteria used for this is: i) <10% canopy density as Sv3, ii) 10-20% canopy density as Sv2 and iii) 20-40% canopy density as Sv1. Scrubland and forest cover with >40% canopy density has considered as no-apparent degradation (NAD).

Changes in the area under different desertification processes during 1991 and 2017 are given in figure 4. Vegetal degradation (including scrub land and forest) has decreased from 23216 ha in 1991 to 20312 ha in 2017. It covers about 62 % of the total area under land degradation (2017). In 1991, area under vegetal degradation with moderate severity (Sv2) was 9904 ha followed by vegetal degradation process with high severity (Sv1) and low severity (Sv3) comprising an area of 3273 ha and 1507 ha respectively (Fig. 3a). similarly, in 2000, the highest area was under Sv2 (10152ha), followed by Sv1 (1141) and Sv3 (873). However, there has been significant increase in the area with high severity (Sv1) comprising an area of 6080 ha followed by Sv2 (5165) and Sv3 (727). There has been significant decrease in the area of scrub land under vegetal degradation during 1991 to 2017 (Figure 4). While comparing the DSMs of 1991, 2000, and 2017 (Fig 3), positive changes (improvement) have been observed in the scrub land in certain areas. This has happened due to the plantation of Prosopis juliflora (sw.) DC and Acacia nilotica (L.) WILLD EX DEL. done by the department of forest under reclamation activity. Figure 3 shows that there is no significant change in the Vegetal degradation process taking place in the forested areas on Aravalli range. In 1991, vegetal degradation in forest areas was 8532 ha, followed by 8990 ha and 8351 ha in 2000 and 2017 respectively.

Total land area undergoing wind erosion was 5475 ha in 1991, which has increased to 5911 ha in 2017 which is covering an area of 15% and 18% of the total degraded area. Area under salinity has also decreased, significantly, over 25 years. In 1991, area under salinity was 5947 ha followed by 5666 ha in 2000 and 49502 ha in 2017. This shows significant decrease in the area affected by salinity over the years. This can be attributed to the restoration activities done by the state authorities by cultivating halophytes. Water erosion have been observed in the scrubland, agricultural land and forest land across the selected time frame. However, area under water erosion was 2020 ha in 1991 has come down to 1309 ha in 2017.

Mining area (both agricultural land and rocky-barren area) was 42 ha in 1991 which has increased to 60 ha in 2000 and 344 ha in 2017. The rocky area was 973 ha in 1991 that declined to 868 ha in 2000 and has reached to an approximate 660 ha by 2017. This decrease is mainly due to mining activity. From 1991 to 2017, there is a significant rise in the area under settlement which has increased from 303 ha (1991) to 2479 ha (2017) due to population growth.

Figure 5A shows developed desertification map on 1:10,000 scale using Resource-sat II LISS IV (2017) data for the Sojat Taluka. Pie-chart representation of the same is given in figure 5B. It is evident that boundaries of principal land degradation processes along with different levels of severity are clearly defined which can be mapped very precisely. This can be attributed to its high spatial resolution (5.8m). Process-wise area covered by different processes are shown in figure 6b. It was observed that about 63% of the area is under Vegetal Degradation (scrubland and forest) comprising an area of 23233 ha. Total land area undergoing wind erosion was 5844 ha which was 16% of the degraded land. Water erosion contributes to 13% covering an area of 4647 ha. Area under salinity was of 5% of the total degraded land. Land undergoing mining activities (both agricultural land and rocky-barren area) was of 300ha. Detailed information gained from DSM map on 1: 10,000 scale would help to prepare action plans for combating desertification at local level.

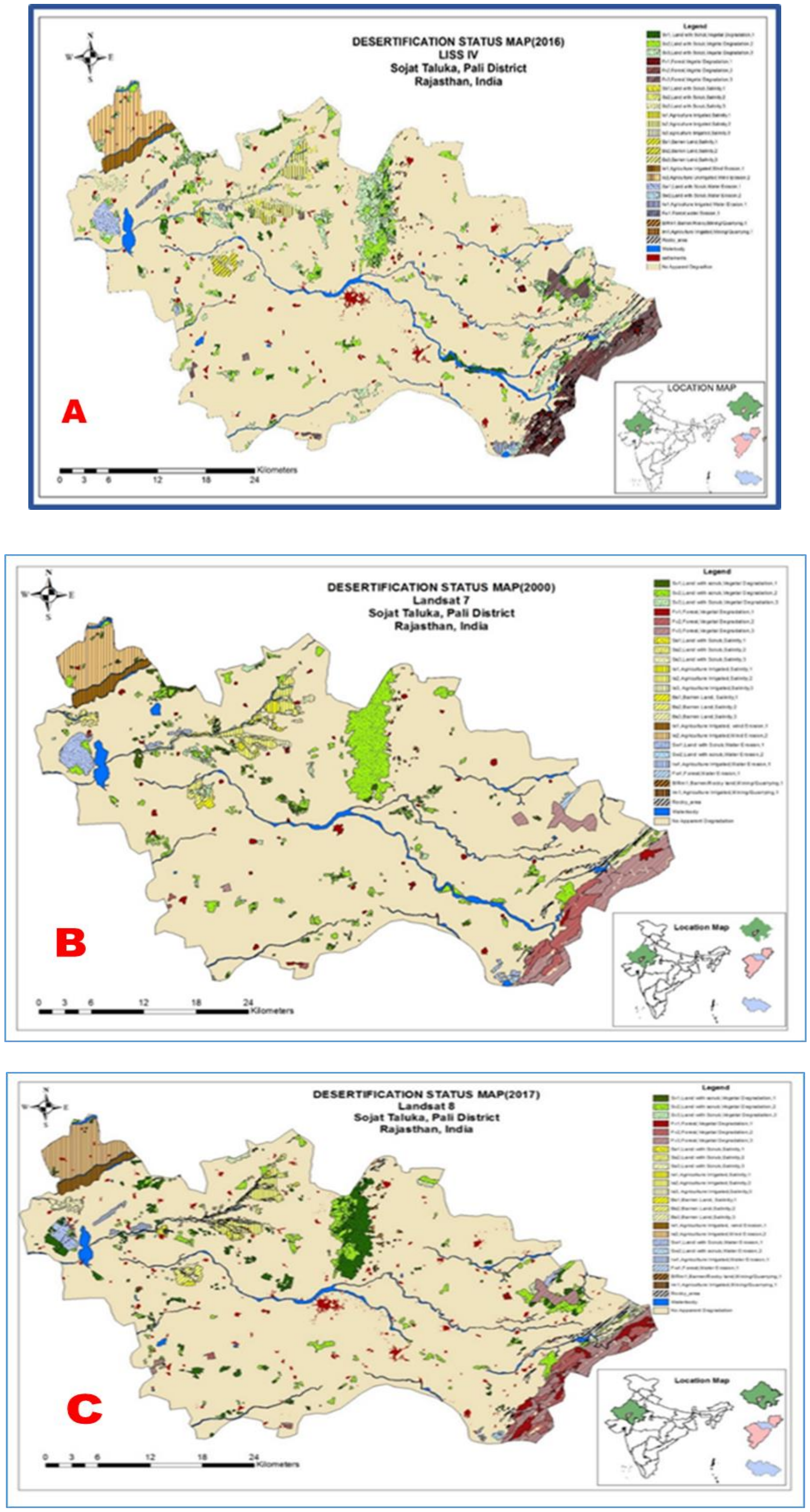

Figure 3: Desertification status map prepared at 1:25,000 scale of Sojat using Landsat data (a) 1991; (b) 2000; and (c) 2017

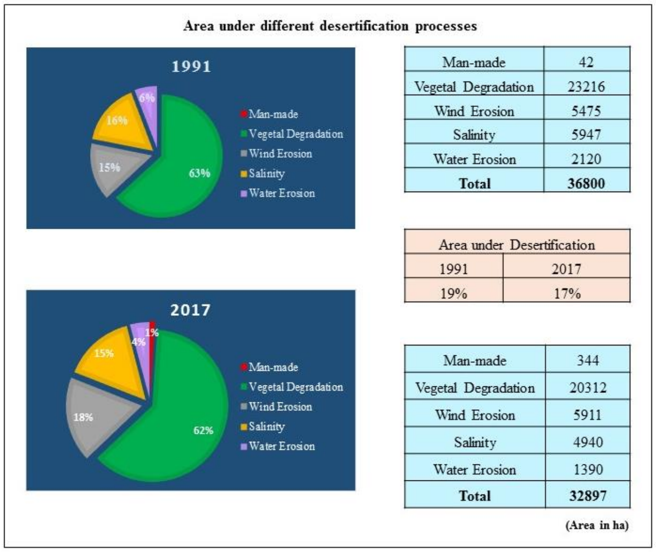

Figure 4: Changes in the area under different desertification processes during 1991 and 2017

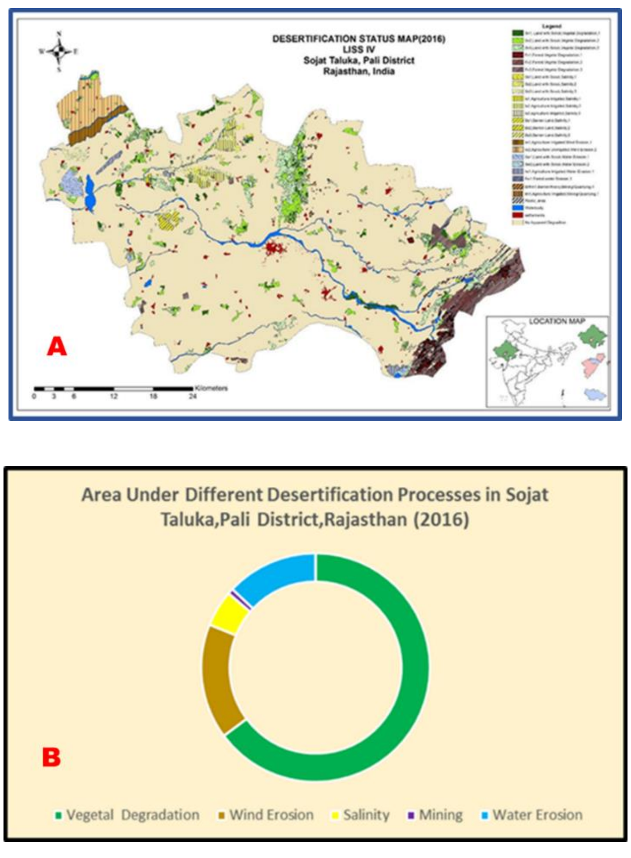

Figure 5: (a - top) Desertification Status Map (DSM) prepared on 1: 10,000 scale of Sojat taluka using Resourcesat II LISS IV (2016); (b - bottom) Pie-chart representation of desertification processes

Conclusion

Desertification status maps (DSM) have been prepared at large scale (1:25,000) using multi-season Landsat TM data, pertaining to the years 1991, 2000 and 2017, for Sojat taluka of Pali district in Rajasthan state of India. These DSM maps have been used for monitoring and assessment of desertification status in the study area over the period of 1991-2017. Vegetal degradation, wind erosion, salinity, water erosion and mining/quarrying are the desertification processes active in this area. Vegetal degradation is the major contributor of land degradation in the study are over 25 years. There has been substantial increase in the area undergoing human induced land degradation (mining and settlement) during the period of 1991-2017. Area under wind erosion has also increased. However, the impact of the implementation of the action to combat desertification, by state government, is clearly visible in the DSM maps. The area under vegetal degradation has significantly reduced due to plantation in scrubland by the forest department. Similarly, the area under salinity has also been significantly reduced during the period of 25 years.

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