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ASSESSMENT OF DIFFERENT INDICES (VEGETATION, SALINITY) AND SALT EFFECTED AREA TREND ANALYSIS USING SHANNON ENTROPY APPROACH – A CASE STUDY IN A SEMI - ARID REGION OF INDIA USING RS / GIS

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Abstract

Though the area under study has a paucity of major environmental resources, it is capable of building up it's own resource base. This can be achieved by developing the naturally thriving salt resistant plants. These in turn shower a positive impact on the economic and environmental resource base of the region and in turn aiming towards sustainable development.

The Landsat TM/ETM+ data was used to monitor the spatio-temporal changes in vegetation condition and soil salinity. To cross check the vegetation cover information and soil salinity obtained through images, ground truth verification of certain sample locations through GPS device was done. Afterwards, vegetation cover map and soil salinity map of 1998 and 2018 were crossed to generate the map of change of vegetation cover and salinity cover for the respective dates and to find out the changing pattern of vegetation cover and soil salinity . Remote sensing based indices like NDVI and NDSI were employed to extract spatial information on vegetation condition and soil salinity of the study area respectively. The soil salinity in terms of NDSI increased in the study area.

The Shannon entropy index was used to understand and quantify the salt effected growth and trend in the study area during the period 1998 to 2018 and to produce land use and cover map for the studied area through the use of the Geospatial techniques with Shannon's Entropy statistical method. For this purpose, three Landsat images were used for land use /land cover classification by using supervised maximum likelihood classification techniques to extract and assess the changes of salt effected area lands. It was concluded that the salinity of the soil has increased down the years. Entropy increased from 0.08 to in the first period to 0.42 in the second. Entropy value increased in the NE, NW, SE and SW zones showed a higher value. This was in bearing with the fact that their was an expansion in the saline land.

Key words: Geospatial Technologies, NDVI, NDSI, Landsat, Shannon Entropy.

Introduction

Environmental degradation is a serious problem posed worldwide. Part of the natural environment undergoes detoriation too (Kundu *et al.*, 2014). Indicators of environmental degradation are loss of biodiversity and natural resources (Walker *et al.,* 2018). These are slow paced and not easily traceable. Environmental changes in the district can be largely monitored by alternation in the vegetation patterns of the area. A number of factors like soil salinity etc., illustrate well the vegetational cover and cropping pattern of a place. Soil salinity is mainly an outcome of weathering of rocks and primary minerals, which are produced in situ and carried from one place to the other through water or wind. Topography, irrigation and dryland salinity are some causes of soil salinity (Biswas *et al.,* 2018). Saline groundwater is brought to the land surface due to clearance of forests, overgrazing and cutting of bushes.

Soil salinity is a major hazard in many arid and semiarid

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regions around the world. About 2 million hectares and 20,000 not only affects plant growth, crop farms across Australia alone show signs of salinity, according to a recent survey.

Salinity production and water quality, but in the long run hampers the economy too. For example, the economic losses due to salinisation in Batinah region in Oman have been estimated at US$ 1604 ha^{-1}(28%) when the salinity increases from low to medium level and US$ 4352 ha^{-1} (76%), if it jumped from low to high level.

Conventionally, soil samples are analysed in the laboratory to ascertain solute concentrations and electrical conductivity. However, they are not time and cost effective.

Remote sensing techniques have been effectively used to map and monitor soil salinity, ever since in 1960s when black and white and color aerial photographs have been used to delineate salt affected soils. Scattered vegetation namely halophytes are indicators of salinity problem, thus making it possible to map affected areas, employing reflectance from vegetation.

Unhealthy vegetation has a lower photosynthetic activity, thus increasing visible reflectance from vegetation and lessened near-infrared reflectance (NIR) from vegetation. This pattern has been found in various plants subject to salinity stress. Several remote sensing indices like NDVI (Normalised Differential Value Index) and NDSI (Normalised Difference Salinity Index) are used to determine the vegetation health, soil salinity of the study area, based on these findings.

In less vegetated areas such as drylands, different proportions between vegetation cover and background soil may demonstrate a relationship between NDVI and vegetation attributes.

The Normalize Difference Vegetation Index (NDVI) is a very a handy technique for monitoring vegetation condition. The Normalized Salinity Index (NDSI) analyses soil containing higher sand particles and has greater reflection in red and less in infra red bands (Tilley *et al*., 2007; Wang *et al*., 2002) .

Shannon's entropy is a statistical analysis for comparing urban spatial pattern (Yeh *et al.,* 2001;Sudhira *et al.,* 2004; Jat *et al.,* 2007), therefore entropy for each zones and time duration must be calculated, and the degree of urban sprawl can be measured by the result of entropy which varies from 0 to log of number of zones and time duration . The more compact of the spatial patterns and the salt effected areas is closer to zeros entropy result, while the closer to the logarithm or number of zones is more dispersed the study area (Sun *et al.,* 2001; Sudhira *et al.*, 2004).

The digital image processing and classification in ERDAS 2014 and the Geospatial Technologies combined with statistical method like Shannon entropy can be used to analyze and demarcation of urban expansion or other land use/land cover classes.

In this particular study the major problem is not urban growth but the major problem is salt effected area growth in the study area that is why we have done deferent approach. In this approach urban growth and urban growth direction we are showing salt growth and salt effected area direction. we are analysis salt effected area with direction and increase or decrease area indication in years 1998 to 2018.

In the past few decades, the area under study,has witnessed conversion into sand dune and meger rainfall. Land, has been largely characterized by the spread of salt effected areas. Shannon entropy will be employed to assess the salt effected growth pattern of the study area, in the past 20 years.

Materials and Methods

Study Area

Churu district (Fig. 1) is situated in the northern part of the state of Rajasthan of India. The study area is located between73°51'49" to 75º01' east longitudes and between 27º24'39" to 28º19' north latitudes. The total population of the district is 2, 041, 171 (2011 census), which is distributed into 7 sub administrative levels (tehsils) towns and 990 villages. Sandy arid plains are stretched throughout the area. The elevation of the study area is between 199 m to 472 meters above Mean Sea Level. Topographically, only a few hillocks and sand dunes are present in the study area and are characterized by light brown sandy soil plains with the low-lying region dominated by scattered vegetative and scanty forest cover.

There is an absence of any perennial river or stream in the district. The principal supply of water is the Indira Gandhi Canal Project and deep wells. The soil is "sandy to loamy, very deep, non-calcareous and has well-drained surface horizon, a slight calcareous, loamy fine sandy B horizon followed by a zone of lime accumulation, partly as concretion" (CAZRI, 1990). The eastern part of Churu is bound by the Shekhawati River Basin which possesses a well-developed drainage system. The rest of the district lies outside the basin. Dungargarh tehsil was part of Churu district till 2012.Since the study undertaken dates back to 1998, the area has been considered for study for data authenticity. (Fig. 1).

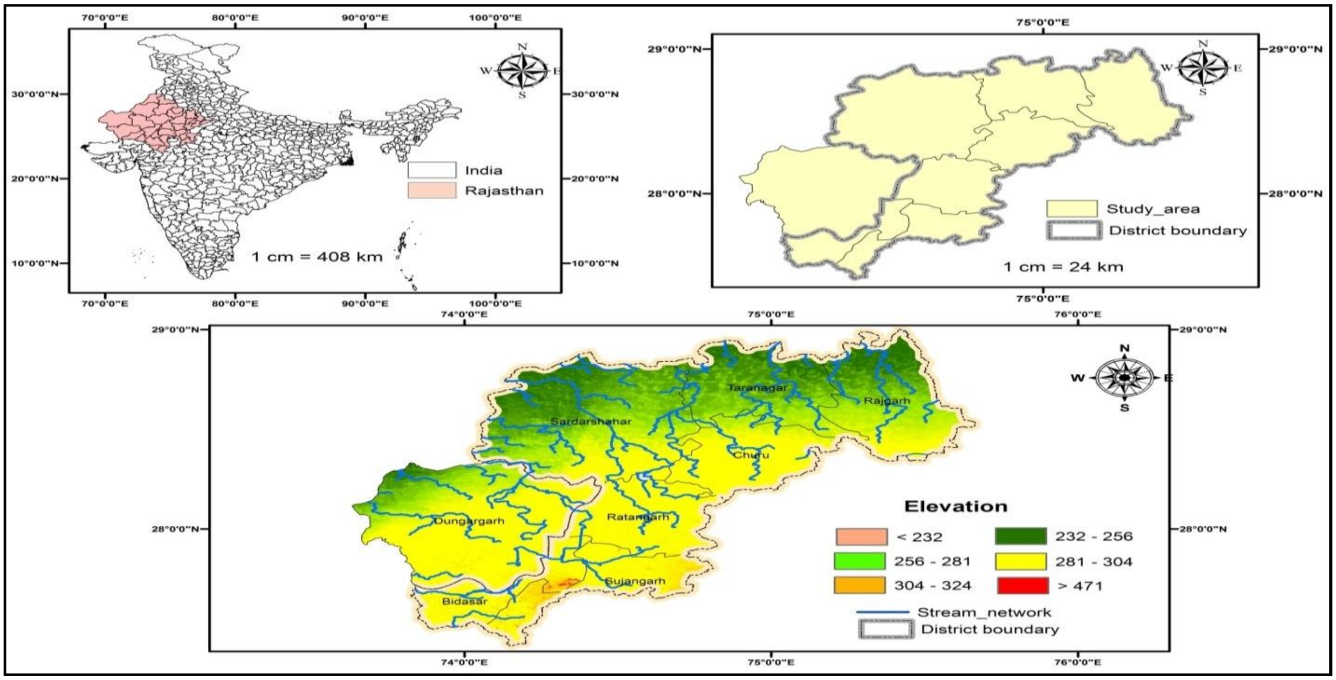

Fig. 1: Map of Study Area

Data set and Methodology

Present study is based on spatial temporal remote sensing data as well as non-spatial data available from various sources for different periods. For multi-temporal vegetation and soil salinity cover, Landsat TM and OLI were taken on September, 1998 and 27 September, 2008 and September 2018 data were obtained from the United States Geological Survey (USGS) databases online resources. USGS satellite data rectified to WGS84 datum and further projected on UTM- 43 north zone based on WGS84. Arc GIS 10.4 and ERDAS IMAGINE 2014 software's have been used for the image processing and Analyze and Monitor the Spatial and Temporal purpose in the study area. The detailed information of the satellite images have been given in Table 1.

Landsat 5/8 NDVI and NDSI indices have been used to carry out the DN value converted into reflectance value . The reflectance images were further processed by using NDVI and NDSI indices and Shannon's Entropy Statistical Techniques as described in Fig. 2.

Converting DNs to Radiance and Reflectance

The raw digital numbers (DN) in the images had

Table 1: Detailed information concerning the satellite data used.

Satellite	Sensor	Path/Row	Acquisition year	Spatial Resolution (m)	Spectral Band(s) (lm)	Data Sources
Landsat -8	OLI/TIRS	148 / 40	10/10/2018	30	B2 (Blue): 0.45–0.51	NASA-Global Land Cover Facility (GLCF) and USGS Landsat 8 OLI-TIRS Series Archive
		148 / 41		30	B3 (Green): 0.53–0.59	
					B4 (Red): 0.64–0.67	
					B5 (NIR): 0.85–0.88	
Landsat -8	OLI/TIRS	148 / 40	10/11/2008	30	B2 (Blue): 0.45–0.51	
		148 / 41		30	B3 (Green): 0.53–0.59	
					B4 (Red): 0.64–0.67	
					B5 (NIR): 0.85–0.88	
Landsat-5	TM	148 / 40	10/11/1998	30	B1 (Blue): 0.45–0.52	
		148 / 41		30	B2 (Green): 0.52–0.60	
					B3 (Red): 0.63–0.69	
					B4 (NIR): 0.76–0.90	

Table 2: Formula used to analyze soil salinity and vegetation indices.

No	Index name	Formula	Reference
1	Normalized Difference vegetation Index (NDVI)	(NIR- RED) / (NIR+ RED)	Khan *et al.,* (2005)
2	Normalized Difference Salinity Index (NDSI)	(RED-NIR) / (RED + NIR)	Khan *et al.,* (2005)

converted into radiance or reflectance before we are done NDVI and NDSI indices in image processing in Arcgis 10.4. Equations rescale the data based on sensor specific information and remove the effects of differences in illumination geometry. It has calculated using the formula as proposed by USGS online resources. Equation 1 depicts the formula of reflectance for the study area.

$$P\lambda = \frac{M\rho * Q\,cal \quad A\rho}{\cos\theta_{SZ}}$$

$P\lambda$ = TOA planetary reflectance

$M\rho$ = Band-specific multiplicative rescaling factor from the metadata.

$A\rho$ = Band-specific additive rescaling factor from the metadata.

Q cal= Quantized and calibrated standard product pixel values (DN).

θ_{SE} = Local sun elevation angle provided in the metadata (Sun Elevation).

θ_{SZ} = Local solar zenith angle; $\theta_{SE} = 90° - \theta_{SZ}$.

Vegetation and salinity indices

The Normalized Difference vegetation Index (NDVI) is a simple numerical indicator that has used to analyze, Monitor the Spatial and Temporal Patterns of the vegetation cover. NDVI is used to distinguish healthy from unhealthy vegetation (Manandhar *et al.*, 2009) using red band and near-infrared band reflectance values and this technique was used in the vegetation condition analysis to delineate between the intensity of green cover and sand land. This was derived using the following equation (Khan *et al.,* 2005).

Soil salinity can be detected directly from remote sensing data through salt features that are visible at the soil surface .it is indirectly from indicators such as the presence of halophytic plant. Salinity indices developed in studies related to soil salinity mapping were examined for all the Landsat images but the most used is two band red and near infrared salinity indices. The spectral radiance of salt affected areas is higher in band 1 & band 3 of Landsat images. So the difference between red or near infrared can retrieved the details information about salt effected area proportion from an image. The Formula of NDVI and NDSI have been shown in Table 2.

Shannon's Entropy and spatial growth pattern of salt effected area

The remotely sensed images Landsat-TM 1998; Landsat-ETM + 2008 and Landsat - 8 2018 were used in this study to derive the salt effected area extents. The supervised classification method started by clipping the satellite imageries using a vector layer of the study area. a supervised classification maximum likelihood technique in Arc map 10.4 was used to classify the clipped images to extract the salt effected areas.

In the study area only two classes were considered, namely: salt effected area class and salt effected area class as shown in Fig. 9. Afterwards, classified imageries were clipped further into 4 zones namely NE, SE, SW and NW. The salt effected area and salt growth for each zone were calculated using Shannon's entropy theory.

Shannon Entropy

Salt effected extinction and Shannon's Entropy

Shannon's entropy method is used to determine whether the growth of vegetation areas was divergent or compact. (Li and Yeh *et al.*, 2004; Yeh and Li *et al.,* 2001);

The Shannon's entropy, Hn is given by Equation.

$$Hn = \mathop{}_{i\ 1}^{n} Pi\log(Pi)$$

$$Hn = \mathop{}_{i\ 1}^{n} Pi\log(Pi)$$

Pi = Proportion of the salt effected areas in the ith zone.

n = Total number of zones.

The value of the Shannon's Entropy is between 0 and log n. 0 means high salt effected areas whereas log n indicates salt effected extinction areas.

Results and Discussion

The Normalized Difference Vegetation Index (NDVI) is a Landsat derived vegetation indicator obtained from the red band and near-infrared (NIR) band ratio of vegetation reflectance in the electromagnetic radiation. Theoretically, NDVI threshold value ranges between -1 to +1. In the study area, NDVI value ranges from between 0.06 to 0.16, average NDVI for the year being 0.1.Measured value range from -0.35 (water) through

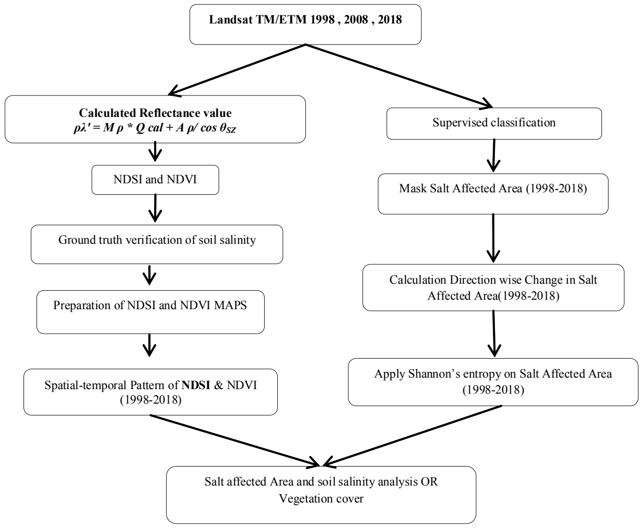

Fig. 2: Flowchart of spatial and temporal changes in NDVI, NDSI and Shannon's entropy.

zero (soil) to +0.6 (dense green vegetation). Thus, scanty to low vegetation can be observed in the area.

The scientific basis of NDVI is that in near infrared band the reflectance from green vegetation is more whereas it is low in red band of the electromagnetic spectrum. Contrary to this, in the Normalized Difference Salinity Index (NDSI), the sand particles have higher reflectance in red band and lesser in near infrared band. The difference between the red and near infrared bands have become beneficial for analyzing, monitoring and measuring extent of soil salinity (Tilley *et al*., 2007; Wang *et al*., 2002).

NDVI value for the year 1998

The analysis of NDSI data of 1998 reveals a high NDVI value of 0.16 in Rajgarh. According to obtained NDVI value for the year, (Fig. 3) a total of 11287.1763 km^2 area had NIL vegetation, whereas scanty and low vegetation was found in 4787.3762 km^2 and 961.4475 km^2 of area respectively.

Owing to higher NDSI value, of the area, scanty or low vegetation cover is observed. Hence, a low NDVI has been observed. As reported earlier, a high NDVI value has been documented in Rajgarh, which can be explained on the basis of geographical location of the place. The area majorily benefits from water supply obtained from Hissar of Haryana.

Major species found in the area include-*Solanum xanthocarpum, Crotalaria burhia, Maytenus emarginata, Ziziphus nummularia* and *Calotropis procera.*

NDVI value for the year 2008

A total of 13929.2712 km^2 area exhibited NIL vegetation. Sparse or scanty vegetation could be observed

Table 1: NDVI statistics.

Tehsils	NDVI 1998	NDVI 2008	NDVI 2018
Rajgarh	0.16	0.11	0.20
Taranagar	0.08	0.04	0.18
Sardarshahar	0.07	0.08	0.18
Churu	0.14	0.09	0.20
Dungargarh	0.09	0.10	0.21
Ratangarh	0.15	0.12	0.19
Sujangarh	0.13	0.08	0.22
Binesar	0.10	0.08	0.20

Source : Computed by the authors

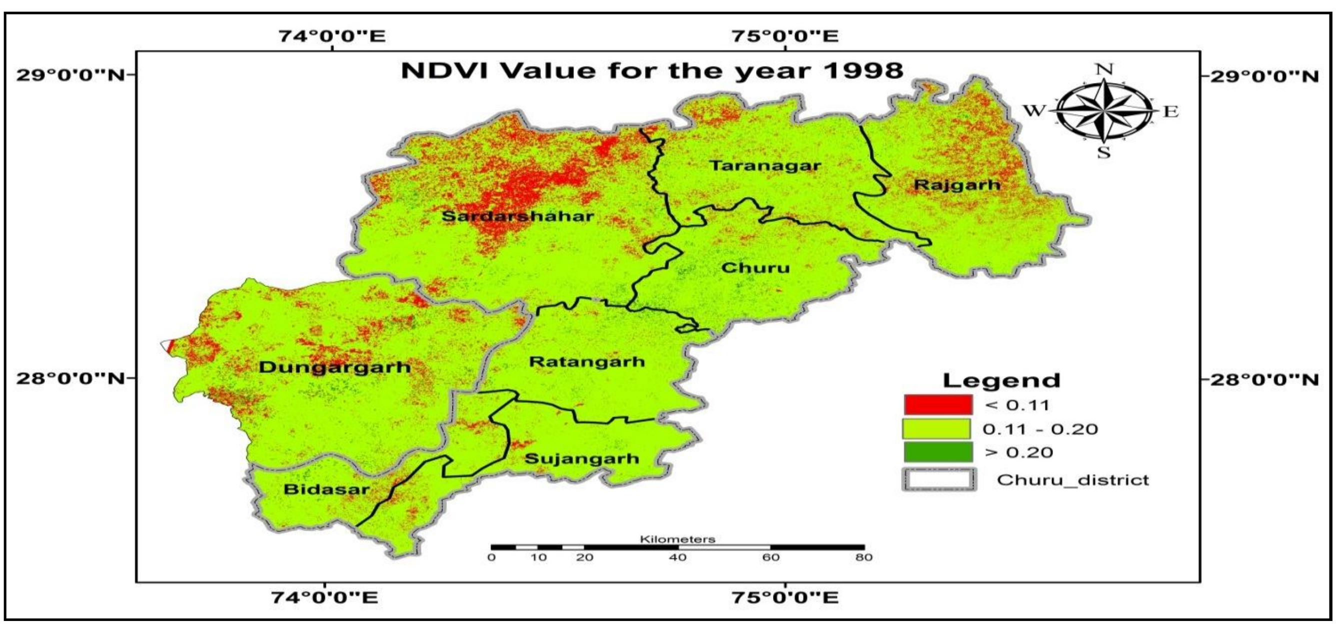

Fig. 3.

in an area of 2891.672 km^2 for the year 2008. Species found in this area were *Solanum xanthocarpum, Crotularia burhia, Aerva tomentosa, Cenchrus biflorus, Dactyloctenium scindicum and Nerium indicum*. However, low vegetation was accounted in an area of 215.1018 km^2. Species found in this area were *Capparis decidua, Cassia auriculata and Albizia julibrissin*.

However, NDVI ranged from 0.08 to 0.11. High NDVI values were recorded for Dungargarh and Rajgarh areas (Fig. 4).Vegetation in these areas comprised of *Prosopis cineria, Tecomella undulate, Leptadenia pyrotechnica, Aerva persica, Salvadora oleoides* and *Acacia nilotica*. Deviating from the average NDVI value for 2008 of 0.08, Taranagar, showed a low value of 0.04.Rainfall in this area dipped to a low of 43.75 mm. This gave rise to drought in 2008.

NDVI value for the year 2018.

The NDVI analysis of the year 2018 was done. An increase in soil salinity is observed. However, an increase in the NDVI value has also been observed. A range of 0.18 to 0.21 was recorded (Fig 5). Interestingly, a stretch of agricultural land was observed in Dungargarh area, giving rise to a high NDVI value of 0.19.The tehsil of Rajgarh also documented an NDVI of 0.19. The vegetation of the tehsil could be categorized into Tropical Evergreen, Tropical Dry Deciduous, Tropical Thorn and Mixed Miscellaneous type of forests.

An area of 15284.1421 km^2 was scantly covered by vegetation like *Zizyphus nummularia, Calotropis procera, Leptadenia pyrotechnica* and *Maytenus emarginata*. Almost an expanse of 540.3726 km^2 had

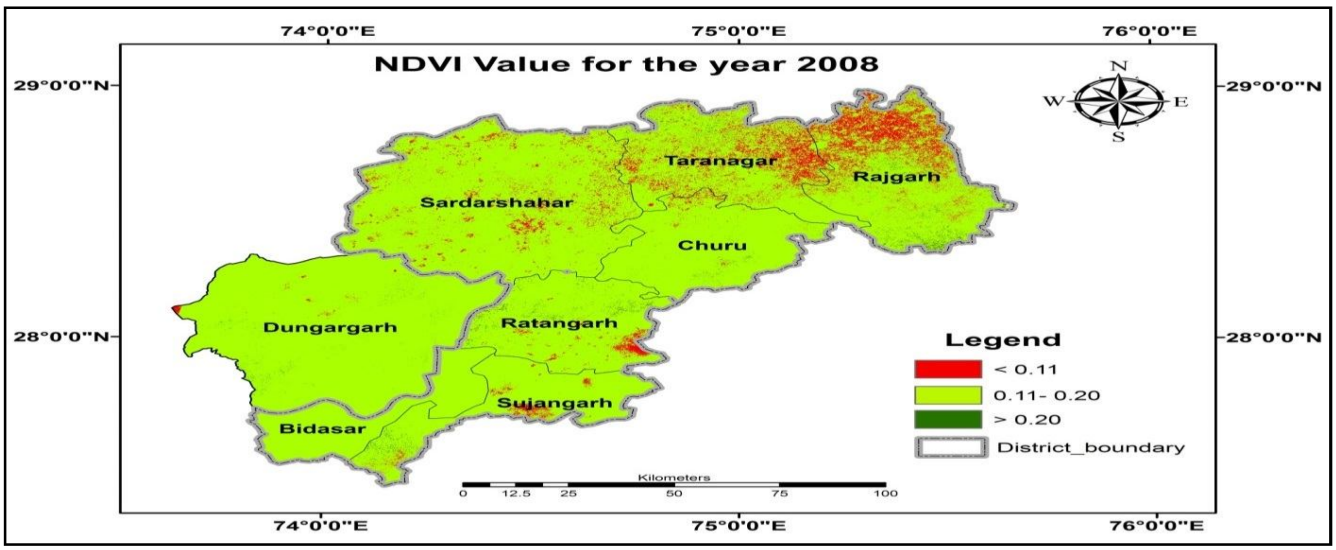

Fig. 4:

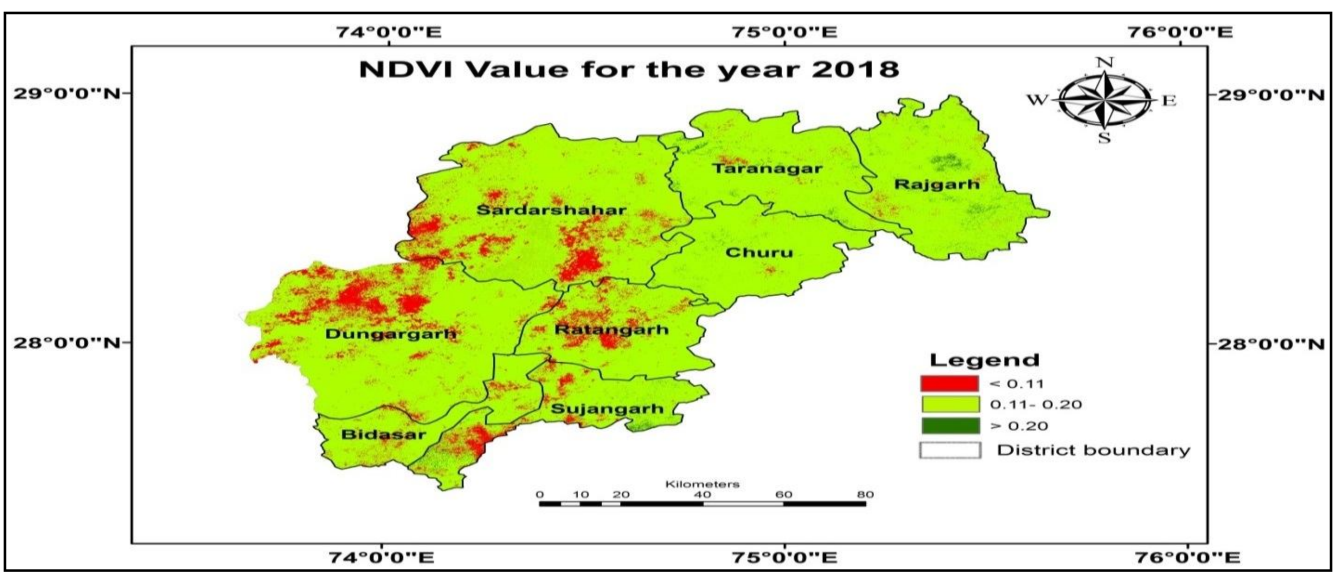

Fig. 5:

Table 2: NDVI derived change statistics of the study area.

NDVI Value based category	NDVI Value threshold	NDVI Value 1998 sq km of category	NDVI Value 2008 sq km of category	NDVI Value 2018 sq km of category
NIL Vegetation	<0.11	11287.176	13929.271	540.3726
Scanty Vegetation	0.11-0.20	4787.3762	2891.627	15284.142
Low vegetation	>0.20	961.4475	215.1018	1211.485

Source : Computed by the authors

Table 3: NDSI statistics

Tehsils	NDSI 1998	NDSI 2008	NDSI 2018
Rajgarh	0.06	0.08	0.10
Taranagar	0.08	0.09	0.11
Sardarshahar	0.08	0.11	0.12
Churu	0.13	0.16	0.18
Dungargarh	0.08	0.10	0.10
Ratangarh	0.12	0.16	0.18
Sujangarh	0.13	0.16	0.18
Bidasar	0.10	0.16	0.18
Average value	0.10	0.13	0.14

Source : Computed by the authors

NIL vegetation. Species like *Azadirachta indica, Ecalyptus globulus* and *Ficus religiosa* were found in an area of low vegetation of 1211.485 km^2.

Infertile conditions, owing to increasing soil salinity yielded a low NDVI of 0.18 in Taranagar and Sardarshahar tehsils.

NDSI value for the year 1998

On determination of NDSI value of the area, it was shown to exhibit a range of 0.06 to 0.14. (Fig. 6) Average value was worked out to be 0.10.The tehsils of Churu and Sujangarh exhibit maximum salinity conditions and hence show a high salinity index of 0.13.As, can be observed, by the vegetation cover of the area, the tehsil of Rajgarh harbours comparatively fertile soil. The same, can be affirmed, by it's NDSI value, which is a low of 0.06.

It has been perceived from ground truth verification and satellite images that, scanty vegetation cover is the main decisive factor towards the presence of salt in the soil. Halophytes are salt accumulators and consequently endeavors towards salt eradication and reduction from soil. Soil salinity relies largely on the presence/absence of these plants.

Total area marking low salinity was 5482.32 sq km. Medium salinity area was 3205.26 sq km and a higher salinity was occupied by an area of 4205.26 sq km.

NDSI value for the year 2008

A range of 0.08 to 0.16 of NDSI was recorded for the year (Fig. 7). The entire area could be divided into lower (10701.24 km^2), medium (12201.2 km^2) and higher (8201.2 km^2) salinity levels. However, an average NDSI of 0.13 was worked out. The areas of Ratangarh, Bidasar and Sujangarh, through their scanty or NIL vegetation

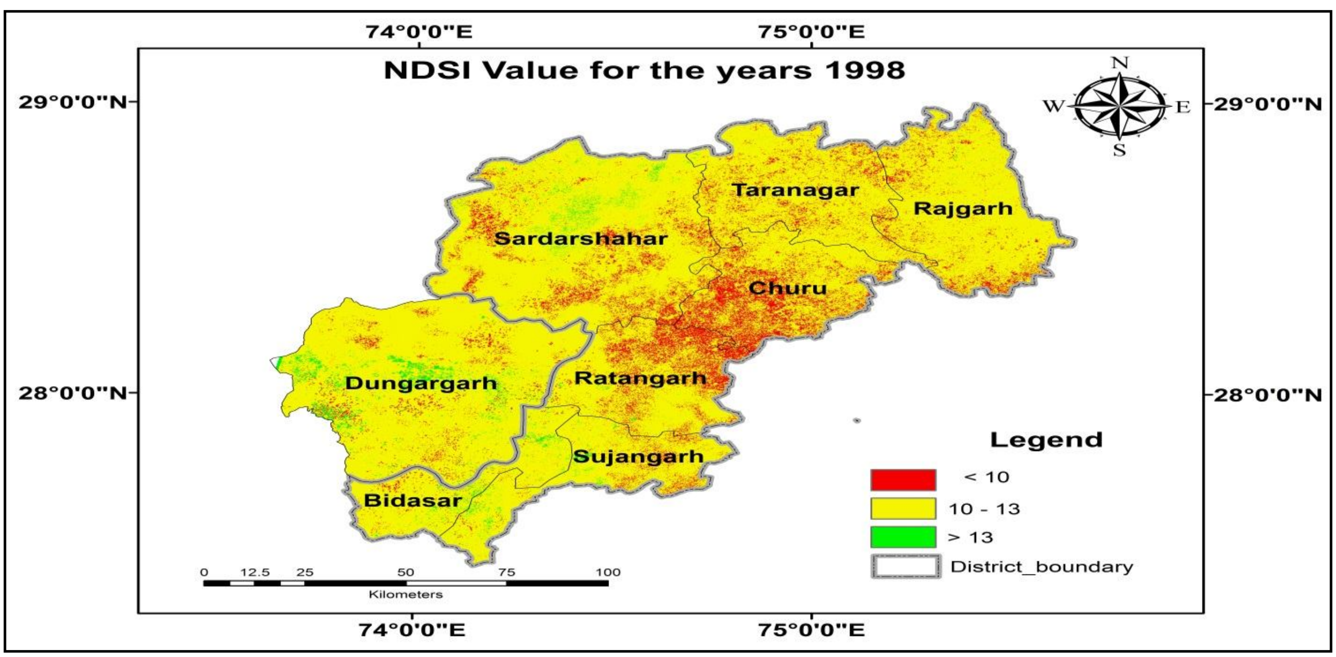

Fig. 6:

have proved the occurrence of a high NDSI value of 0.16 in the area. The fertile zone of Rajgarh, once again, showed a low NDSI of 0.06.

The level of precipitation and water supply is inversely related to soil salinity. Lower values of soil salinity and NDSI have been observed in those parts where precipitation is relatively higher and has a satisfactory water supply. Percolation of water till deep water table also helps in washing away of salt. In 2008, the area experienced severe drought. A lot of tehsils experienced higher value of NDSI (kundu *et al*., 2014), this is, in accordance with the fact stated above, that NDSI value is inversely proportional to water supply.

NDSI value for the year 2018

A decade from 2008, the year 2018 saw an increase in sand dunes. Also, weather conditions turned more arid. All factors contributing to increased salinity levels. Highly saline soil was found in an area of 852.44 km^2. An area of 10701.24 km^2 was covered with medium saline soil. Low salinity was recorded in an area of 5482.32 km^2.

The average NDSI for the year was 0.14. Tehsils of Ratangarh, Bidasar and Sujangarh showed a high value of 0.16 (Fig. 8). Range of NDSI value was 0.10 to 0.18 for the year. Again Dungargarh and Rajgarh, where some cropping pattern is observed showed low NDSI value of 0.10.

Salt effected area trend analysis using Shannon Entropy (1998-2018)

The study area was done supervised classification indicated increases in salt effected area day by day due

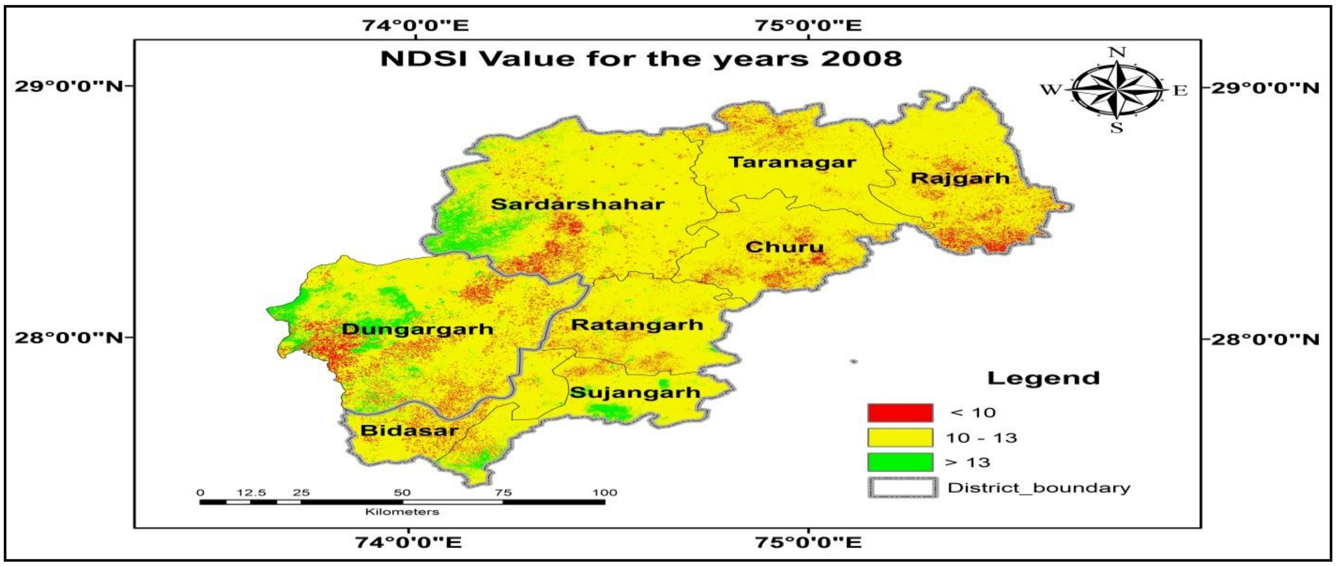

Fig. 7:

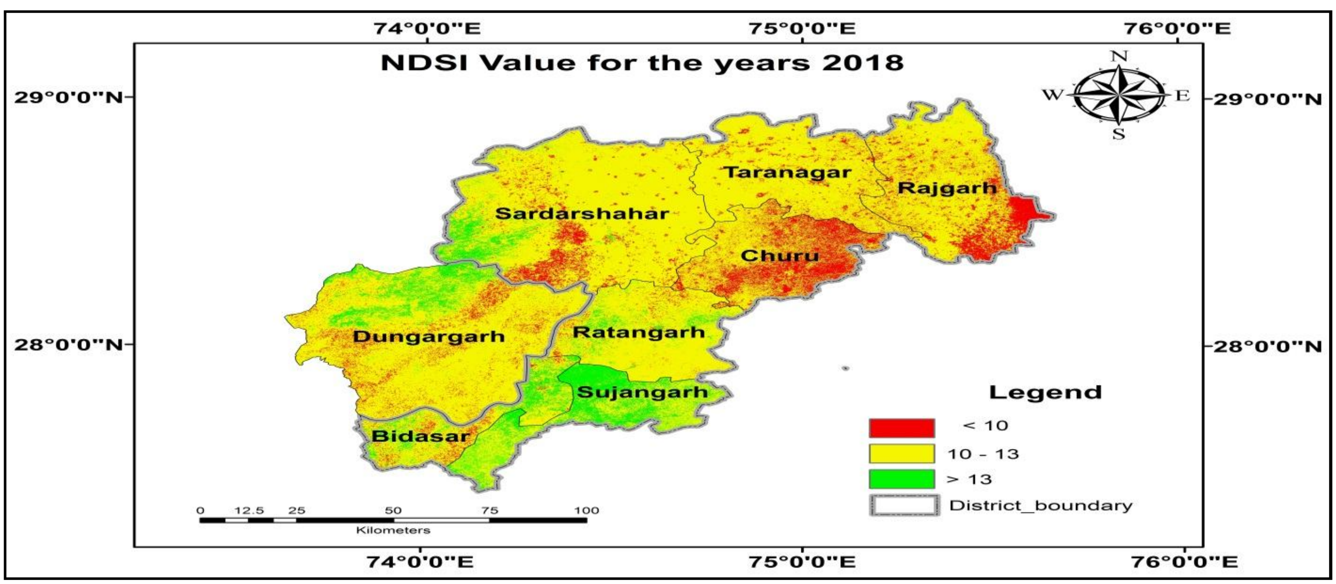

Fig. 8:

Table 4: NDSI derived change statistics of the study area

NDSI Value based category	NDSI Value threshold	NDSI Value 1998 sq km of category	NDSI Value 2008 sq km of category	NDSI Value 2018 sq km of category
Low salinity	<0.10	5482.32	3205.26	4205.26
medium salinity	0.10- 0.13	10701.24	12201.2	8201.2
High salinity	>0.13	852.44	1629.54	4629.54

Source : Computed by the authors

Table 5: Tehsil wise salt effected area of the study area (1998, 2008, 2018).

Tehsil	LU/LC (1998)	LU/LC (2008)	LU/LC (2018)
Churu	0.16	1	14.3703
Dungargarh	1.7055	4	28.1231
Rajgarh	0.0108	1	6.3081
Ratangarh	0.7074	2	11.9331
Sardarshahar	5.2056	17	20.826149
Sujangarh	7.2063	10	49.9761
Taranager	0.2061	9	11.9556

Source: Computed by the authors

to low vegetation cover. the tehsil wish growth pattern of Salt affected areas which seems to be Sujangarh, Sardarshhar, boundary part of Sri Dungargarh and Ratangarh a major problem of this semi-arid region. Sujangarh mostly at Chhapar, Parihara and South of Sujangarh tehsil.

The major concentration among the natural salt effected area was found in two tehsil Sujangarh and Sardarshhar. This was found mainly locales in village of sujangarh tehsil Beer Chhapar, Tharda, Abasar, Parihara, Harasar, Bheenwsar, Dhatri, Loha. In Ratangarh tehsil village was found Ladhasar, Gogasar. Sardarshhar tehsil village was found Amarsar, Sadasar, Hardesar and Dungargarh was found village Udasar Charnan.

The trend and growth of Salt Affected Area was analyzed and the percent of Salt Affected Area for the two time period was computed (Table 6). As shown in Figure 9, the Salt Affected Area in 1998 was 15 km^2, which increased to 45 km^2 in the year 2008 and 140 km^2 in 2018 with an increase of 30 km^2 in the first period and 95 km^2 in the second period. The average annual growth rate was 1.48 and 0.99 percent respectively. During the period 1998-2008, the non-forest areas have registered a declining trend while there is an increase in Salt Affected Area and sandy area by 22.2%, while the period from 2008 to 2018. The growth of Salt Affected Area is mainly towards the southwest and northwestern part of the study area.

The study area was divided into four zones (NE, SE, SW and NW) to evaluate the trend and direction of growth of Salt affected areas which seems to be a major problem of this semi-arid region. Table 3 shows the Salt affected area for each zone of each classified image while Table 4 shows the observed growth in Salt affected area for 4 zones in the 2 time period and Table 5 shows the forest growth rate for each time period.

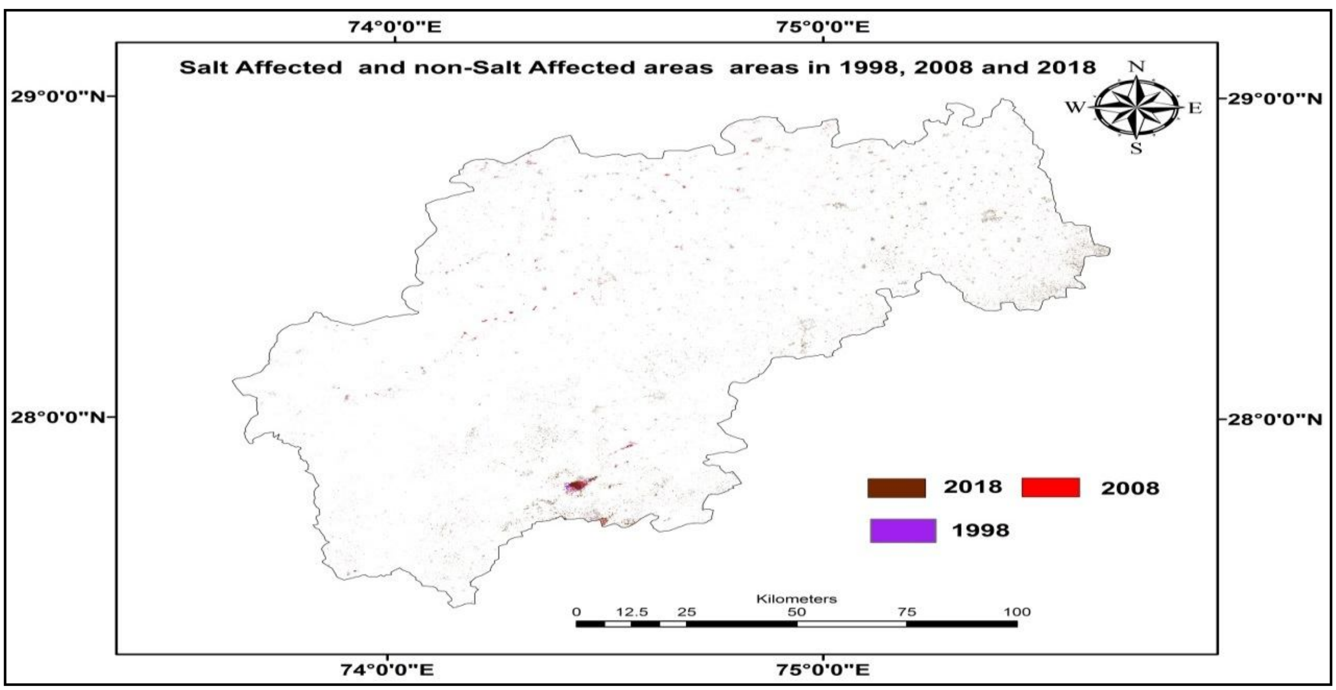

Fig. 9: Directions - Change in Salt Affected Area - 1998 to 2018.

Table 6: Salt Affected areas (in km^2) in all zones from 1998 to 2018.

Years	SE(Area)	SW(Area)	NE(Area)	NW(Area)
1998	0.2835	8.4933	1.584	4.8384
2008	0.783	13.2876	15.1371	15.7005
2018	50.4715	13.8307	58.0255	16.4999

Table 7: Observed increased in salt affected areas (Km^2).

Years	SE(Area)	SW(Area)	NE(Area)	NW(Area)
1998-2008 change	0.4995	4.7943	13.5531	10.8621
2008-2018 change	49.6885	0.5431	42.8884	0.7994

Table 8: salt affected areas increased rate (km^2/year) for the 2 time periods.

Rate of expansion	SE(Area)	SW(Area)	NE(Area)	NW(Area)
1998-2008	1.761905	0.56448	8.55625	2.244978
2008-2018	63.45913	0.040873	2.83333	0.050916

Table 9: Shannon's entropy for the two time periods (n = 4).

Time Period	Entropy	Log(n)	1/2 Log(4)
1998-2008	0.08	0.43	0.21
2008-2018	0.42	0.43	

Conclusion

Change in forest cover of Churu district and Dungargarh during 1998 to 2018 has been attempted in the present paper. The forest cover type in the study area generally includes open reserved forest, Mixed Miscellaneous, Tropical Dry Deciduous, Tropical thorn and Tropical Evergreen forests and open scrub land. Three NDVI value threshold of < 0.11,0.11-0.20 and > 0.20 were undertaken. To increase in scanty and low vegetation, there is an increase in the area in the threshold category of < 0.11. Three NDSI value threshold of < 0.10, 0.10-0.13 and > 0.13 were undertaken. The study period along with major increase in NDSI area of the threshold of > 0.13.

The increasing trend in the salinity of the Churu district was computed and assessed using three Landsat images during 1998 to 2018 and also by combining GIS, remote sensing and Shannon entropy. Statistical techniques were employed to evaluate the effect of salinity and to prepare land use and land cover map for the studied area. Hence, the above conclusions were drawn. Therefore, it is being suggested that with reliable data, and effective management, salt affect into land use/land cover ought to be monitored and managed for sustainable development and to protect the land use/land cover of the environmental resources.

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