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ORIGINAL ARTICLE

Assessment of spectral indices analysis (vegetation and soil salinity) using remote sensing techniques and statistical approach in the Churu district, Rajasthan (India)

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ABSTRACT
Vegetation change is a slow and gradual process that is difficult to classify exclusive of long term multi-temporal data. The Landsat TM/ETM+ data along with multi-temporal was used to monitor the Spatio-temporal changes in soil salinity and vegetation condition pattern of the study area. Remote sensing-based indices such as NDVI and NDSI were applied to evaluate the spatial information about vegetation condition and soil salinity of the study region respectively. The soil salinity in terms of NDSI was higher while NDVI was lower in the semi-arid regions of Rajasthan, India. The results of the correlation coefficient were very weak between NDVI and NDSI (1998-2008).
Key words: *Vegetation condition, NDVI, NDSI, spatial information.*

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INTRODUCTION

Geospatial techniques have extensively been used to map and evaluate soil salinity, since in 1960s while monochrome and color airborne photographs have been used to elucidate salt affected soils. Sparse natural floras, including halophytes, are markers of the issue of salinity, allowing the use of reflectance from natural vegetation to map affected regions. Unhealthy vegetation has a poorer photosynthetic activity, therefore increasing visible reflectance from vegetation and decreasing near-infrared reflectance (NIR) from vegetation [12]. This pattern has been found in different plants subject to salinity stress. Based on these findings, multiple remote sensing indices such as NDVI (Normalized Differential Value Index) and NDSI (Normalized Difference Salinity Index) are being used to assess the vegetation condition and soil salinity of the study area. Different proportions between vegetation cover and background soil can show a relationship among NDVI and vegetation attributes in the less vegetated areas like semi-arid regions or dry lands. The Normalize Difference Vegetation Index (NDVI) is a very a useful technique for examining and planning of natural vegetation. The Normalized Salinity Index (NDSI) studies soil having higher sand particles and have greater reflection in red and less in infra-red bands [10] [13].
Statistics are used to describe and explain the statistics in the numerical form from experiments in which the information is gathered. The most commonly used techniques for investigating the relationship between two quantitative variables are correlation and linear regression. Correlation quantifies the frequency of the linear association between two variables, while the association in the form of an equation is represented by regression. For example, in natural vegetation attending saline and less saline, we could use correlation and regression to determine whether there is a relationship between vegetation condition and saline soil and whether the level of health of vegetation can be predicted for a given saline soil [9] [1].

MATERIAL AND METHODS

The Churu district (Figure 1) is situated in the northern part of Rajasthan, India. It occupies a total geographical area of 13,859 sq. km. It lies between the coordinates 73º51'49" to 75º01' east longitudes and 27º24'39" to 28º19' north latitudes with an elevation of 292 m. According to the 2011 census, the total population of the district is 2,039,547. This small population is distributed into 7 sub administrative levels (tehsils) towns and 990 villages [4]. The arid sandy plains extend all over the place [11]. The topography of the region is well characterized by undulating sandy plains crossed with longitudinal dunes, with heights ranging from 6 to 50 meters above mean ground level extending north-east to south-west [6]. The ground slopes from northeast to south. The area has altitudes which vary from 195 to 472 meters above Mean Sea Level. The maximum temperature reaches more than 41°C during summer while in winter the minimum temperature goes as low as 4.6°C (Weather-atlas) [8]. It receives 381 mm of annual rainfall (Climate-data) [2]. The major food-grain crops grown in Churu are bajra (*Pennisetumglaucum*), wheat (Triticum aestivum), barley (*Hordeumvulgare*) and maize (Zea mays); oilseeds such as groundnut (*Arachishypogaea*), sunflower (*Helianthus annuus*) as well as mustard (*Brassica juncea*) (Districtsofindia.com).

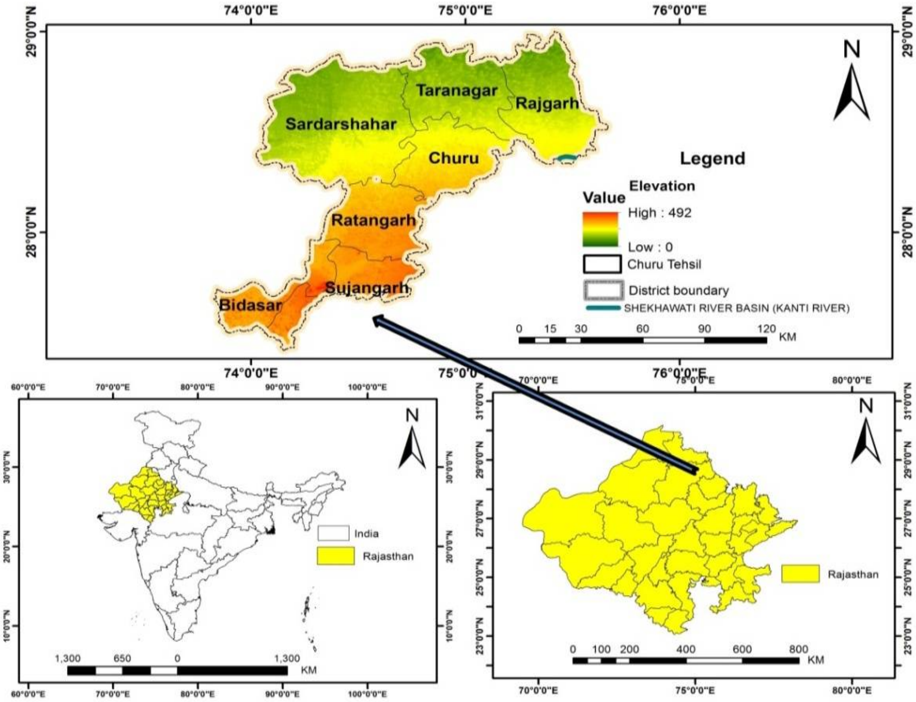


Figure 1: Location map of the study area

Multi-temporal Landsat-5 to Landsat-8 satellite images were obtained from the USGS Earth Explorer website. The image processing of the images was performed using various software namely ERDAS IMAGINE (2014), Arc GIS (ver. 10.4), ENVI (ver. 5.3). Atmospheric corrections were carried out on the obtained Landsat-5 and Landsat-8 images where the DN values were converted into reflectance value in ArcGIS (ver. 10.4) software. The information acquired by the field survey was used as primary data as well as for accuracy assessment.

The multi-temporal satellite image is more suitable as it contains sufficient information about the phenology of the vegetation and Spatio-temporal change in the physical characteristics. The Spatio-temporal study consists of multiple images and atmospheric correction is suitable for the satellite imageries [3].

Converting DNs to Radiance and Reflectance

The raw digital numbers (DN) in the images are converted into radiance or reflectance value after the processing of NDVI and NDSI in ArcGIS 10.4. The equations rescale the data based on the sensor to acquire the precise information and to remove the effects of differences in illumination geometry. Equation (1) depicts the formula of reflectance and has been proposed by USGS.

$$\lambda P = M\rho * Q\,cal\, A\rho / \cos\theta_{SZ} \qquad (1)$$

λP= 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; θSE = 90° - θSZ.

Vegetation and salinity indices

Normalized Difference vegetation Index (NDVI)

The Normalized Difference vegetation Index (NDVI) is a simple numerical indicator that is used to examine and monitor the Spatio-temporal patterns of the vegetation cover over a geographical area. NDVI is used to distinguish between healthy and unhealthy vegetation [7] using red band and near-infrared (NIR) band reflectance values. This method was used in the vegetation analysis to define the intensity of green cover. It was derived using the following equation (2) [5].

NDVI = (NIR- RED) / (NIR+ RED) (2)

Normalized Difference Salinity Index (NDSI)

Soil salinity can be sensed directly from multi-temporal (satellite imagery) data through salinity traits that are noticeable at the soil surface. It is indirectly from indicators such as the existence of the halophytic plants. Salinity indices developed in the study associated with soil salinity mapping were observed for all the Landsat images in which two bands namely, red and near-infrared are used majorly for salinity indices. The spectral radiance of salinity affected areas is superior in band 1 and band 3 of Landsat images. As a result, the variation between red or near-infrared can provide detailed information about the salt-affected area from an image. The equation (3) defining NDSI is as follows [5]:

NDSI = (RED-NIR)/ (RED + NIR) (3)

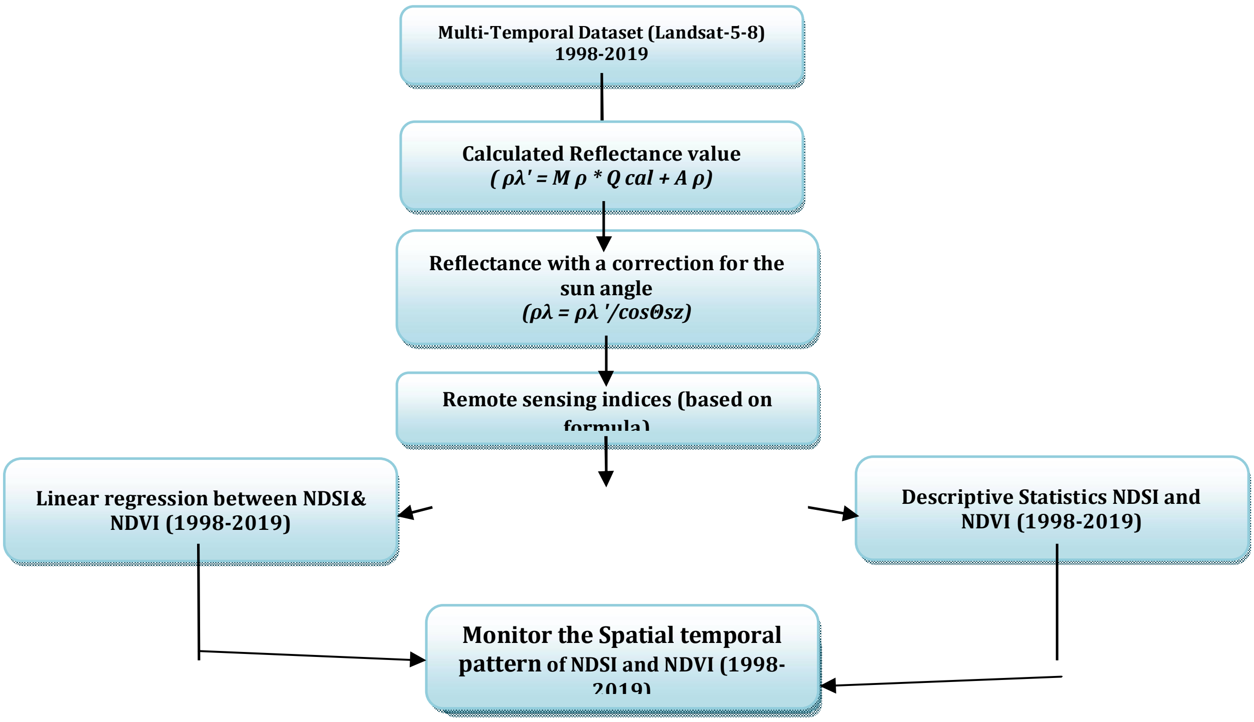


Figure 2: Flowchart of the mythology

RESULTS AND DISCUSSION

The Normalized Difference Vegetation Index (NDVI) is a satellite-derived vegetation indicator acquired from the red band and near-infrared (NIR) band ratio of vegetation reflectance in the electromagnetic radiation (EMR), while in the Normalized Difference Salinity Index (NDSI), the sand particles show higher reflectance in red band and lesser in near-infrared band. The differences between the red and near-infrared bands have turned out to be useful for analyzing, monitoring and calculating the level of soil salinity [10] [13].

Table 1: NDVI and NDSI values for the year 1998, 2008 and 2019

Tehsils	NDSI	NDVI	NDSI	NDVI	NDSI	NDVI
	1998		2008		2019	
Rajgarh	0.05	0.16	0.07	0.14	0.10	0.21
Taranagar	0.07	0.10	0.10	0.04	0.11	0.10
Sardarshahar	0.09	0.09	0.11	0.09	0.12	0.17
Churu	0.12	0.14	0.14	0.10	0.20	0.21
Ratangarh	0.11	0.12	0.17	0.11	0.19	0.17
Sujangarh	0.14	0.12	0.17	0.09	0.19	0.13
Bidasar	0.11	0.11	0.16	0.07	0.17	0.21

In the study area, the NDVI value ranged from 0.04 to 0.21 during the years 1998-2019 which indicated a scanty to low vegetation in that area. The tehsils like Rajgarh and Bidasar had NDVI value 0.21 observed in the year 2019 which was higher than other years. NDSI value was found to be increased from the years 1998 to 2019. Churu showed a higher NDSI value of 0.20 in the year 2019 while Rajgarh tehsil showed a lower NDSI value of 0.05 in the year 1998. The values between NDVI and NDSI showed an inverse relationship where a low NDSI resulted in a higher NDVI value and vice-versa as shown in table 1.

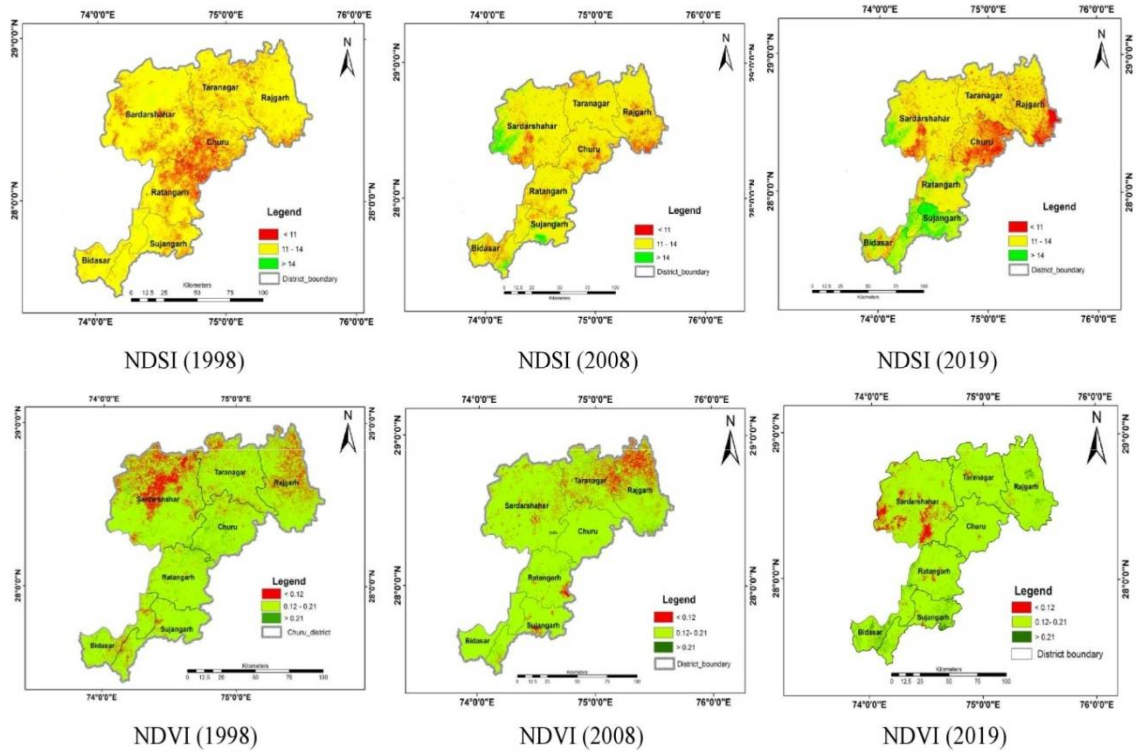


Figure 2: NDSI and NDVI maps of Churu district, Rajasthan

In the above figure (2), the Spatio-temporal changes of NDSI and NDVI over the Churu district of Rajasthan have been shown. It depicts the response of vegetation growth and vigor with respect to the change in salinity inside the soil.

Descriptive Statistics of NDSI and NDVI value in years 1998, 2008 and 2019

Table 2: Descriptive Statistics of NDSI and NDVI value in years 1998, 2008 and 2019

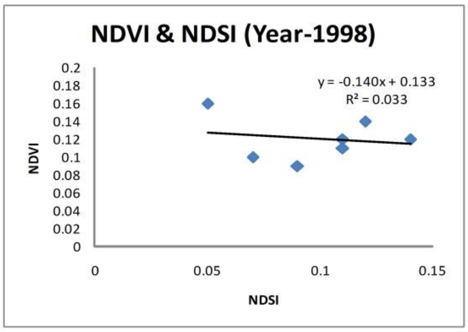
	NDSI	NDVI	NDSI	NDVI	NDSI	NDVI
Descriptive Statistics	1998		2008		2019	
Mean	0.10	0.12	0.13	0.09	0.15	0.19
Median	0.11	0.12	0.14	0.09	0.17	0.21
Mode	0.11	0.12	0.17	0.09	0.19	0.21
Standard Deviation	0.03	0.02	0.04	0.03	0.04	0.04
Sample Variance	0.00	0.00	0.00	0.00	0.00	0.00
Kurtosis	-0.50	-0.02	-1.22	0.85	-2.39	2.00
Skewness	-0.44	0.62	-0.53	-0.18	-0.29	-1.40
Range	0.09	0.07	0.10	0.10	0.10	0.13
Minimum	0.05	0.09	0.07	0.04	0.10	0.10
Maximum	0.14	0.16	0.17	0.14	0.20	0.23
Confidence Level (95.0%)	0.03	0.02	0.04	0.03	0.04	0.04

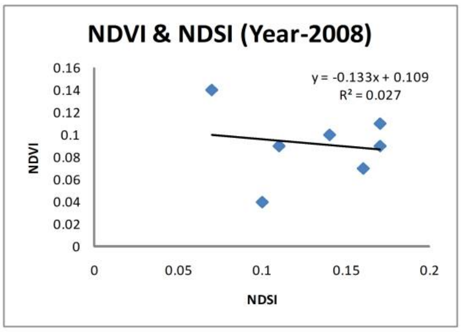
The descriptive statistics show that the mean NDSI for the years 1998, 2008 and 2019 are 0.10, 0.13 and 0.15 respectively; while the mean NDVI for the years 1998, 2008 and 2019 are 0.12, 0.09 and 0.19 respectively. The maximum NDSI was found to be 0.20 while the minimum was 0.05. The NDVI showed its maximum value as 0.23 while a minimum value of 0.04 (Table 2).

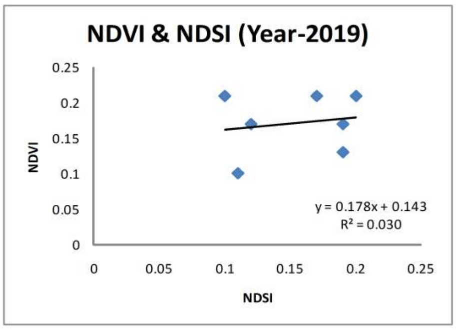
Statistical analysis between NDVI and NDSI value

Linear regression between NDVI and NDSI for the years 1998, 2008 and 2019

Second order polynomial regression was applied and the relationship between NDVI and NDSI values area shown in the figures 3.







Correlation Analysis between NDVI & NDSI

Year	correlation (r)
1998	0.182
2008	0.164
2019	0.173

Figure 3: Linear regression between NDVI and NDSI for years 1998, 2008 and 2019

Correlation analysis results between NDVI and NDSI was higher with a value of 0.18 in the year 1998 as compared to the values of the years 2008 and 2019. The overall analysis showed a very weak correlation or slight relation between NDVI and NDSI. In the study area, most of the places are covered with saline soil and saline or no water. Therefore, the vegetation growth depends upon harvested rainwater.

CONCLUSION

In this research work, an attempt has been made to show the relationship between NDVI and NDSI over the study area by creating spatio-temporal maps using Landsat 5-8 satellite image, where the response of vegetation with change in soil salinity can be evaluated. The results of NDVI value ranged from 0.04 to 0.21 during the years 1998-2019, which signified sparse and low vegetation in the area. NDSI value was found to increase gradually from the year 1998 to 2019. Churu has a highest NDSI value i.e. 0.20 during the year 2019 while Rajgarh tehsils was found to be the lowest value of 0.05 in the year 1998. The results of correlation coefficient analyses between NDVI and NDSI showed a weak and slight correlation.

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