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Assessment of soil salinity by geo-spatial technology in Ballia district of Uttar Pradesh

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Abstract: Soils vary in their characteristics from one place to another place due to interactions of soil forming and processes. Assessment of spatial and temporal variation of characteristics is needed for any mean or use it's crucial to take into account the diverse spatial differences in soil properties, which has long in this context. Geographic information system (GIS) technology has enormous potential in the field of soil's assessment for upgrading soil statistic systems for an accurate and cost-effective means of understanding changes in the landscape. The future agricultural monitoring of the nutritional quality of the soil in diverse regions and villages is crucial. In this paper assessment of spatial variation of soil salinity using GIS techniques around the Ballia District of Uttar Pradesh is presented from the year 1994 to 2019. Normalized Difference Salinity Index (NDSI) was used. It showed increasing trend in salinity from 1994 to 2019 for each block. Using Landsat (TM/OLI) imageries with a 30 m spatial resolution, the spatial distribution of salinity from 1994 to 2019 was determined and low negative NDSI value was observed from -0.143 to -0.117 in the southeast part of Ballia which can be an important explanation for soil degradation due to increasing soil salinity.

Keywords: *Spatial variation, geographic information system (GIS), soil salinity, normalized difference salinity index (NDSI), landsat, soil degradation*

Introduction

Land degradation evaluation using geospatial technology involves assessing the changes in land quality and productivity over time using satellite imagery, geographic information systems (GIS), and remote sensing techniques (Huete *et al*. 2008; Singh *et al*. 2017). Land degradation is a significant environmental challenge that threatens the sustainability of ecosystems and livelihoods in various regions around the world (Bishop *et al*. 2001). It refers to the deterioration of the quality and productivity of land, often caused by natural processes and human activities. Soil degradation is a problem which is prevalent in many parts of our country, India (Singh *et al.* 2022). But its severity from local scale to country level is not be understood clearly (Bassett and Zueli 2000). Land degradation may cause decrease in crop productivity which is the resulting factor of human and climatological activity (Meng *et al.* 2020). The utilization of geo-spatial technology, encompassing satellite imagery, remote sensing, and geographic information systems (GIS), has emerged as a powerful tool for assessing and monitoring land degradation over time (Maya *et al*. 2015). This study focuses on applying these advanced techniques to

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evaluate land degradation in the Ballia district of Uttar Pradesh. The district's economy heavily relies on agriculture, making the preservation and sustainable management of its land resources crucial for food security and economic stability. As district is susceptible to land degradation due to factors such as unsustainable land use practices, deforestation, urban expansion, laboratory analysis of soils at various level of salinity is detected by combining the proximal and remote sensing data. Analyzing the spatio-temporal pattern of NDSI in relation to salinity involves observing how NDSI values change across both space (different areas) and time (different points in time) in satellite imagery and same has been used in the assessment of salinity in Ballia district.

Materials and methods

Located in the eastern part of Uttar Pradesh, India (25°23 to 26°11; 83°38 to 84°39), Ballia District is characterized by its diverse landscapes, including agricultural lands, forests, water bodies, and urban areas. It has cool and dry winter and summer season is very hot with daily maximum even touching 47ºC in the months of May-June. The district often suffers from the floods. There are three distinct seasons, i.e., winter or cold season (November to February), summer or hot season (March to June) and rainy or monsoon season July to October (Tripathi 2008). The primary objective of this study is to employ geo-spatial technology to assess and analyze the extent of land degradation in Ballia district over a specified period. The insights gained from this analysis will help in better understanding of the drivers of land degradation in the district and formulating an appropriate land management strategies.

Demographic profile

As per the Census of 2011, the district has 1,087 population density per sq. km. The population which was 2,761,620 in 2001 increased to 3,239,774 in 2011. In the year 2011, total male and female population is 1,672,902 and 1,566,872 respectively in the district. The decadal growth rate of population is recorded as 17.31 per cent between the year 1991 to 2001 and 22.07 per cent between the year 2001 to 2011. Rural and urban population is 24, 91,676 and 2, 69,944, respectively in 2011.

Normalized Difference Salinity Index (NDSI)

NDSI (Normalized Difference Salinity Index) is used to detect saline and non-saline soils. Salinity index was the ratio of red band to near infrared (NIR) band, while NDSI is the ratio of the difference of the red to NIR divided by the summation of the two. Values of NDSI approaching +1 are associated with high soil salinity (Odeh *et al.* 2007).

Soil salinity indices are principally adjusted to detect salt mineral in soils based on the different responses of salty soils to various spectral bands.

The following equation to map soil salinity was used after (Elhag 2016):

NDSI = $(G X R)/B$

Where, B is the Blue band

G is the Green band

R is the Red band

Ground Truth data

Ground truth refers in various fields, including remote sensing, machine learning, and scientific research, ground truth data serve as a reference or benchmark against which other data sources or analytical methods are validated or compared. About 77 ground control points (ground truth) and soil sample were collected for each stratum.

Preparation of Thematic maps:

The Thematic maps showing salinity status generated using the analytical data. The point data collected using GPS was then transformed into polygon data using kriging interpolation technique in ArcGIS software 10.3.

Results and discussion

For a period of 26 years (1994-2019), Landsat data were utilised for image interpretation to compute various indices useful for assessing soil deterioration, such as NDSI. From 1994 through 2019, the mean NDSI value increased for each block. From 1994 to 2019, NDSI was strongly correlated with the downward trend in rainfall, which ultimately reduced the crop yield *via* decreased soil quality. The results of ground testing are consistent with the indices chosen from Landsat data and stand as the best explanation for the soil degradation.

Normalized Difference Salinity Index (NDSI)

Spatial distribution of salinity from 1994 to 2019 derived using Landsat (TM/OLI) imageries at 30 m spatial resolution presented in fig. 2. Variation in NDSI for the month of October based on the annual mean in the area was calculated as -0.448 to -0.119, -0.402 to -0.053 and -0.295 to -0.0237 for the year 1994, 2004 and 2019 respectively (Fig. 1). The NDSI increased from northwest to southeast over the year from 1994 to 2019 (Fig. 2). Low negative NDSI value was observed from -0.143 to -0.117, was located in the southeast (Hanumanganj, Belhari, Murli Chhapra, Bariya) of Ballia. NDSI is used for temporal and spatial trend changes detection in the soil salinity and its relation with vegetation. NDSI has a negative correlation with NDVI. High vegetation cover with lower value of NDSI was observed in the western Ballia (Pandah, Nagra and Rasra), in the northwest region, which was detected as highest negative NDSI in Nagra (-0.448), in Nagra the high negative NDSI values (-0.448) was also observed in Pandah (-0.398) and Rasra (-0.389) showing a higher decreasing value of NDSI from 1994 to 2019 due to increasing salinity, a causative factor of degradation.

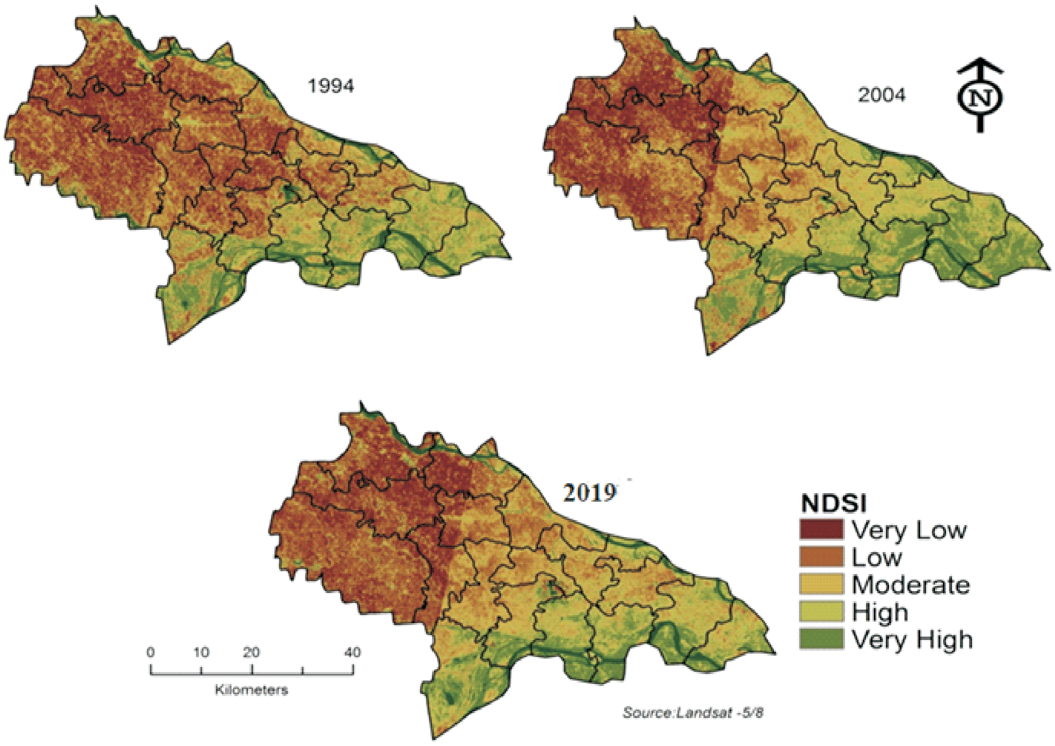

Fig.1. Normalized Difference Salinity Index (NDSI).

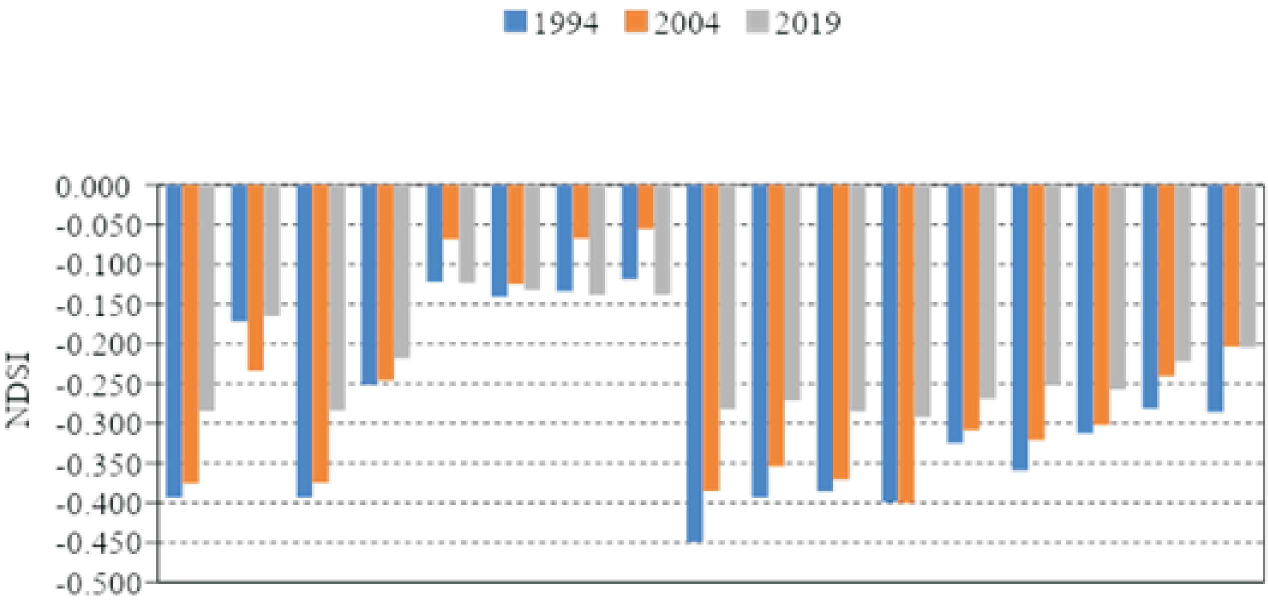

Fig. 2. Spatio -temporal pattern of NDSI (1994-2019).

NDSI showed increasing trend from 1994 to 2019 for each block, however it was highest in southeast (Murlichhapra, Bariya and Belhari) and low in northwest (Nagra, Rasra and Pandah). This might be associated with high salt content, lower vegetative growth and barren land as indicated by linear spectral unmixing (LSU) for decadal period from 1994-2004 to 2019.

Conclusion

The identification and mapping of degraded soil resources in the region, as well as the marking of decadal changes over a period of 26 years, were accomplished using datasets created from Landsat (TM/OLI) imageries at 30 m spatial resolution for the month of October for the period from 1994 to 2019. Degraded soils were found to be the least suitable for growing crops while the block Pandah and Bansdih were found to be the best suitable followed by Siar's block soil.

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