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Original Article

Soil Salinity Mapping and Evaluation based on Normalized Difference Salinity Index - A Case of Daund Tahsil, Pune District, Maharashtra

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Abstract

Soil salinization is a severe problem in the present-day context, particularly for the arid and semi-arid regions of the World. The primary causes of increasing soil salinity are excessive and improper irrigation practices, the overuse of chemical fertilizers, and a monocropping pattern of water-intensive cash crops. The study area selected for the present research work is Daund Tahsil in Pune District of Maharashtra. Soil salinity is mainly observed in continuous patches, particularly in the north-western part of the study area. The present research aims to delineate areas covered by saline soils. Remotely sensed data in the form of satellite imageries and DIP (Digital Image Processing) techniques are highly effective in the generation of various salinity indices and thereby the detection of soil salinity. Satellite imageries can also be used to monitor both spatial and temporal variations of soil salinity. A LANDSAT 8 OLI (Operational Land Imager Sensor) satellite image (2017) was used for estimating the NDSI (Normalized Difference Salinity Index) and preparing the soil salinity map of Daund Tahsil. The NDSI considers the Near Infrared (NIR) band and Red (R) band for estimating soil salinity. According to the calculated NDSI, the study area has been categorized into four classes, viz., highly saline, moderately saline, slightly saline, and non-saline land. The highly saline land covered a major part of the study area among saline land classes.

Key Words: *Soil salinity, LANDSAT 8 OLI, NDSI, Near Infra Red band, Red band, Saline land.*

Introduction

Soil salinization has become a severe environmental problem, especially in arid and semi-arid regions. Soils containing high to very high proportions of salts are known as saline soils. The monocropping pattern of water-intensive cash crops such as sugarcane, over irrigation, and excessive use of chemical fertilizers have led to the development of saline soils. High to very high salinity negatively affects crop growth and productivity, ultimately leading to land degradation. Land degradation has become a serious issue in India, and particularly in Western Maharashtra, due to the large-scale irrigation and expanding land area under sugarcane cultivation. In Maharashtra, a significant proportion of all canal command areas is waterlogged and saline, thereby making land not available for cultivation. Due to the same monoculture cropping pattern of sugarcane being practiced continuously for many years and excessive application of water to the crop, the land has become waterlogged and saline. The monoculture cropping pattern is observed in more than two-thirds of the irrigated area in Kolhapur, Pune, and Sangli districts of Maharashtra. Daund Tahsil, followed by Baramati Tahsil, has the largest areas under saline or alkaline soils in Pune District. The salt encrustations are noticeable during the dry season of the year, which leads to the development of the fallow lands in the study area. Thus, the major challenge is to reduce and prevent further spread of saline lands and to sustain agricultural land in Daund Tahsil. To properly manage saline soils in the study area, the extent of saline soils needs to be demarcated accurately.

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Remote sensing data has enormous potential to assess the extent, degree of severity, and spatial distribution of saline lands. Remotely sensed data and techniques are highly effective in detecting soil salinity by generating various vegetation and salinity indices.

Study Area

The study area is Daund Tahsil, which has a total geographical area of 1360 square kilometers. Daund Tahsil is situated in the eastern part of Pune District in Maharashtra. Daund Tahsil extends from 18° 17' to 18° 40' North latitudes and 74° 08' to 74° 50' East longitudes (Figure 1). The study area is geologically a part of the DBP (Deccan Basalt Province). The maximum part of the Daund Tahsil has a plain physiography. The area under study has a tropical climate highly influenced by the southwest monsoon rainfall. The type of climate of Daund Tahsil is semi-arid. According to Koeppen's climatic classification system, the study area experiences 'Aw' (Tropical Savanna) type of climate. Daund Tahsil is situated on the southern bank of the Bhima River. The Bhima River and its tributaries, namely, Mula-Mutha, are the major rivers in the study area. In Daund Tahsil, the natural vegetation is tropical dry deciduous, except along the river Bhima, where it is mixed deciduous vegetation. The soils of Daund Tahsil are basically grouped into the following four categories: moderately shallow to deep (> 50 cm), shallow soils (25-50 cm) confined to hill ranges, very shallow soils (10-25 cm) in between hill ranges and plains, and extremely shallow soils (less than 10 cm). The soils are mostly fine-textured and well-drained black soils and medium-textured in some patches. Moderately shallow to deep soil covers the maximum portion of the study area. Deep black soil is found along the low-lying areas of the Bhima and Mula-Mutha rivers. This soil is clayey, well-drained, and it is dark brown to greyish black in colour. The soil can support crops such as sugarcane, jowar, bajra, groundnut, and onion. This soil is suitable for the cultivation of crops when supplemented by irrigation.

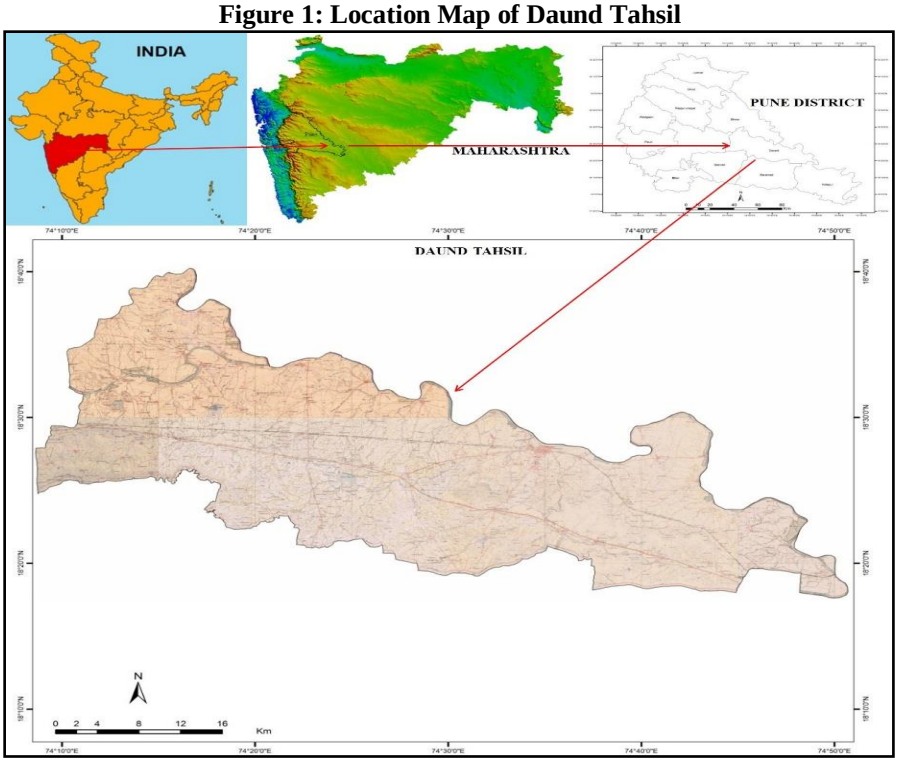
Daund town is the headquarters of Daund Tahsil, and it is the main marketplace and one of the two major urban areas in this predominantly rural area. Agriculture is the dominant activity practiced by the people living in the Daund Tahsil. Crops such as sugarcane and wheat are cultivated in deep black soil in the low-lying areas of the Bhima and Mula-Mutha rivers in the study area. The principal cash crop in the study area is sugarcane. A significant land area of Daund Tahsil is irrigated, mainly used for sugarcane cultivation. A number of sugar-based industries are located in the study area.

Objectives

In the present research paper, soil salinity in Daund Tahsil of Pune District has been analysed using the Normalized Difference Salinity Index (NDSI). The objectives of the present study are:

(i) To estimate the Normalized Difference Salinity Index (NDSI) for estimating soil salinity in the study area.
(ii) To analyse spatial variations in the Normalized Difference Salinity Index (NDSI) in the study area.
(iii) To delineate areas having saline soils in the study area and group them into different categories of soil salinity.

Figure 1: Location Map of Daund Tahsil



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Database

(i) Topographical Maps: SOI (Survey of India) Toposheets on 1:50,000 map scale have been used as base maps. Survey of India Toposheets: 47 J/2, 47 J/3, 47 J/6, 47 J/7, 47 J/10, 47 J/11, and 47 J/15, covering Daund Tahsil, have been georeferenced in ArcGIS software and merged. The georeferencing of the base map has been performed in ArcGIS software. The stream network, contours, railway lines, roads, wells, etc., have been digitized using SOI Toposheets.

(ii) WRIS Data: Data about physical and hydrological characteristics of soils has been obtained from the WRIS (Water Resources Information System) - a Web GIS portal of India.

(iii) DEM: The ASTER GDEM (Advanced Spaceborne Thermal Emission and Reflection Radiometer - Global Digital Elevation Model) data of 30 meters spatial resolution of the Daund Tahsil has been used for the preparation of the elevation and slope (%) maps.

(iv) Satellite Imageries: LANDSAT-8 OLI (Operational Land Imager) satellite image (spatial resolution of 30 meters) has been used for the estimation of soil salinity index - NDSI (Normalized Difference Salinity Index) and preparation of the Soil Salinity Map of Daund Tahsil.

(v) GPS Data: The entire study area has been tracked with the help of a Garmin GPS (Global Positioning System) for ground truthing. The soil sample points and salt encrustation spots were tracked by using GPS to acquire the location data.

Methodology

Remotely sensed data, i.e., satellite imageries and DIP (Digital Image Processing) techniques, are extremely effective in the generation of various vegetation and salinity indices and the detection of soil salinity. In the present research work, the NDSI (Normalized Difference Salinity index) has been estimated. The NDSI is a ratio involving the Red and Near Infrared bands.

Formula for the calculation of the NDSI (Normalized Difference Salinity Index):

NDSI = (R – NIR) / (R + NIR) - Khan et al., 2005

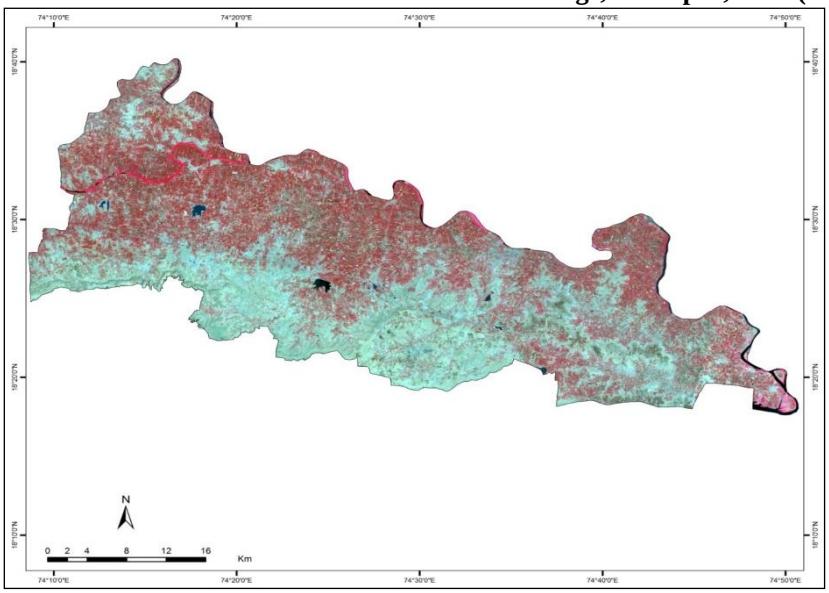
Where

R = reflectance value of the red band of the LANDSAT 8 satellite image

NIR = reflectance value of the near infrared band of the LANDSAT 8 satellite image

The NDSI takes into account the Near Infrared Band and Red Band for estimating the soil salinity. The brightness values in white encrustations can be considered as salt-encrusted land.

Figure 2: Daund Tahsil – Landsat-8 OLI Satellite Image, 17th April, 2017 (FCC)



The locations of salt encrustations in the study area (Figure 4) have been mapped using a Garmin GPS (Global Positioning System) device. The validation of the soil salinity index – NDSI derived from the satellite data has been accomplished mapping locations of salt encrustations by GPS field survey.

Results

The quantitative analysis of soil salinity index – NDSI (Table 1 and Figure 3) highlights that highly saline land covers a large area of Daund Tahsil (~24%), in the western, northern, central, eastern, and southeastern parts. Moderately saline lands (~20%) are present in patches in close association with highly saline lands in the western,

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northern, central, and eastern parts. Slightly saline lands are mainly found in valleys in the southern part and also in patches in association with highly saline lands. This category of land indicates the severity of the salinization problem because land falling under this category is an indicator that the soil salinization problem has just started in this zone.

Figure 3: Daund Tahsil – NDSI (Normalized Differential Salinity Index)

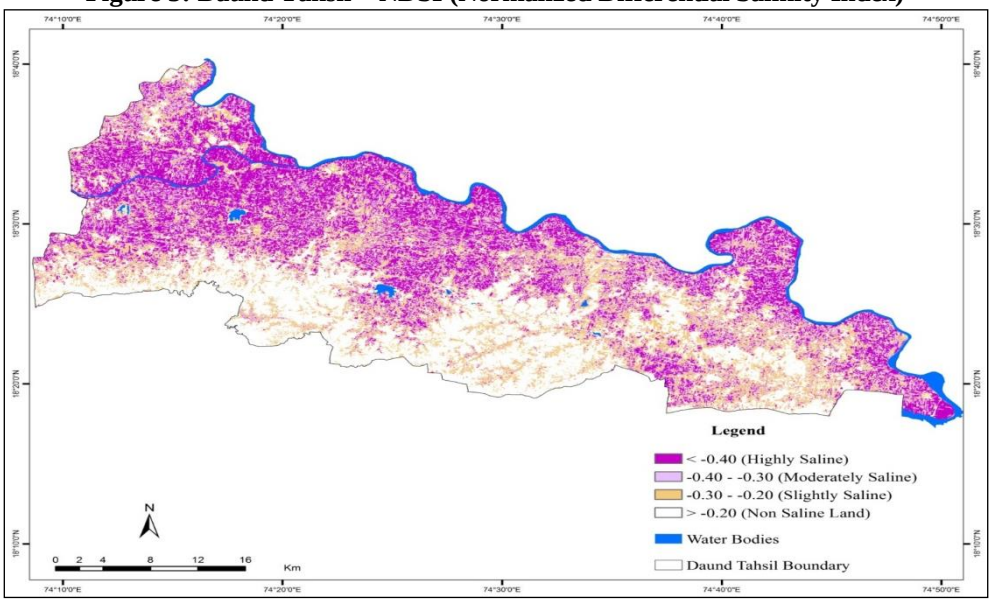
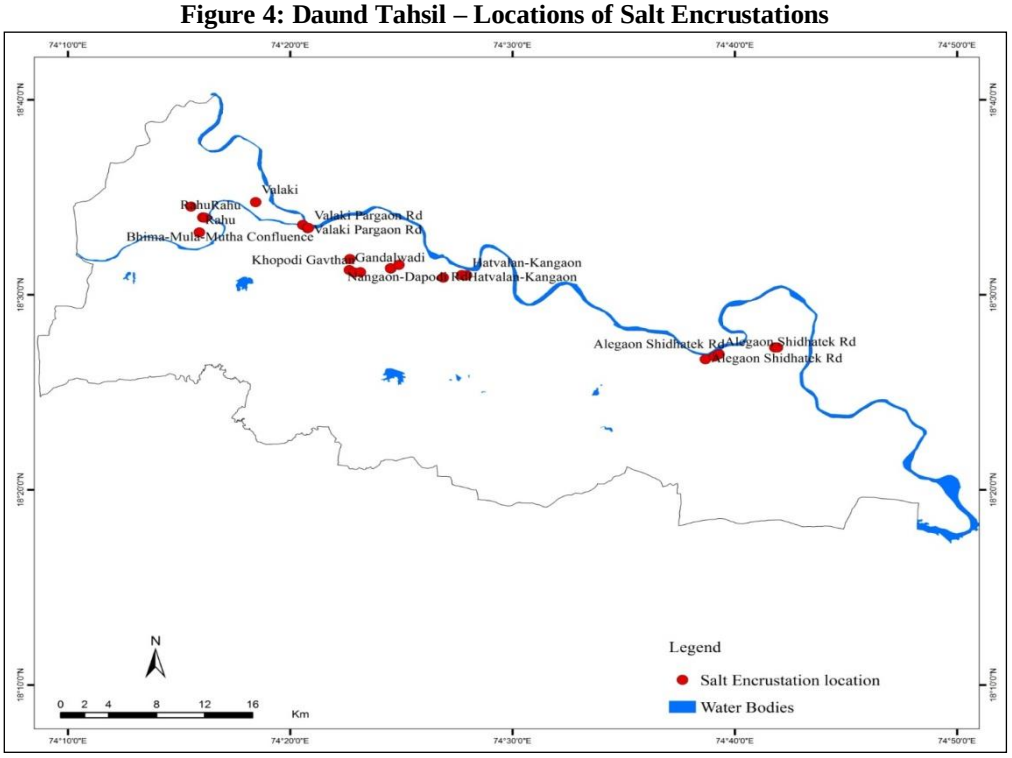


Table 1: Area under various classes of soil salinity in Daund Tahsil according to NDSI

S. No.	Classes (NDSI values)	Area (sq. km)	Area (%)
1	Highly Saline (< -0.40)	323.62	23.79
2	Moderately saline (-0.40 to -0.30)	272.05	20.00
3	Slightly saline (-0.30 to -0.20)	314.36	23.11
4	Non-saline land (>-0.20)	373.71	27.47
5	Water bodies	76.65	5.63
	Total	1360.39	100.0

Figure 4: Daund Tahsil – Locations of Salt Encrustations



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Conclusion

The canal-irrigated sugarcane cultivating areas in the Daund Tahsil have become waterlogged, and the agricultural fields have been degraded by the conversion of a maximum area into saline land in Daund Tahsil. The salinity index – NDSI has revealed the spread of saline soils in Daund Tahsil. If suitable remedial measures are not undertaken immediately, the area under saline land will continue to grow and multiply every year.

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