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Monitoring and Analysis of Degraded Land in Rasulabad Block of Kanpur Dehat District Using Remote Sensing and GIS Techniques

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Abstract:** Land degradation is seen as a development or additional that reduces current and/or potential soil capability to produce products and goods. This implies a decline from a higher to a lower state due to a decline in land capacity, productivity, and biodiversity loss. This can be both natural and human-induced. Natural causes embody earthquakes, tsunamis, droughts, avalanches, landslides, volcanic eruptions, floods, tornadoes, and wildfires. Whereas human-induced soil degradation results from land clearing and deforestation, inappropriate agricultural practices, improper management of industrial effluents and wastes, over-grazing, careless management of forests, surface mining, urban sprawl, and commercial/industrial development. Inappropriate agricultural practices embody excessive tillage and use of heavy machineries, excessive and unbalanced use of inorganic fertilizers, poor irrigation and water management techniques, chemical or pesticide overuse, inadequate crop residue and organic carbon inputs, and poor crop cycle planning. Some underlying social causes of soil degradation in Asian nation square measure land shortage, decline in per capita land handiness, economic pressure onto land, land occupancy, poverty, and population increase.. The aim of the current study is to prepare baseline data to combat land degradation and conserve land resources in an economical and efficient manner. To assess land degradation with the help of Remote Sensing (RS) and Geographical Information System (GIS) – in Rasulabad Block of Kanpur Dehat district, Uttar Pradesh, different levels of analysis were performed to estimate the extent of land. Degradation to assess saline or salt-free soils and calcareous or sodium soils and to match this data with satellite studies. The spatial variability of these soil parameters was shown in soil maps created in a GIS environment. A temporary study of the 2017 and 2021 Sentinel satellite datasets was done to find the parameters that are responsible for land degradation. The severity of land degradation was calculable quantitatively by analyzing the physico-chemical parameters within the laboratory to see salinity and sodicity of soils and further correlating them with satellite-based studies. The pH varied between 7.1 and 8.2, electrical conductivity (EC) between 0.23 and 0.6 miliSiemens/m and the methyl orange or total alkalinity between 0.095 and 0.225 (HCO_3) gL-1 as $CaCO_3$. The spatial variability in these soil parameters was pictured through soil maps generated in a GIS environment with the help of IDW Interpolation. The results revealed that the soil in the study area was exposed to salt intrusion, most of the soil samples of the study area were slightly or moderately saline with a few salt-free sites. Moreover, the majority of the soil samples were calcareous and a few samples were alkaline or sodic in nature.

Keyword: Land degradation, Sodic land, Saline land, GIS, IDW Interpolation.

I. INTRODUCTION

Land degradation is not being adequately addressed, but is of vital importance to raise awareness so that future land management decisions can lead to more sustainable and resilient agricultural systems. Of India's total geographical area (328.7 Mha), 304.9 Mha comprise the reporting area with 264.5 Mha being used for agriculture, forestry, pasture and other biomass production. The severity and extent of soil degradation in the country has been previously assessed by many agencies (Fig. 1). According to the National Bureau of Soil Survey and Land Use Planning ~146.8 Mha is degraded. Water erosion is the most serious degradation problem in India, resulting in loss of topsoil and terrain deformation. Based on first approximation analysis of existing soil loss data, the average soil erosion rate was ~16.4 ton ha−1year−1, resulting in an annual total soil loss of 5.3 billion tons throughout the country. Nearly 29% of total eroded soil is permanently lost to the sea, while 61% is simply transferred from one place to another and the remaining 10% is deposited in reservoirs.[1]

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Organizations	Assessment Year	Reference	Degraded Area (Mha)
National Commission on Agriculture	1976	[3]	148.1
Ministry of Agriculture-Soil and Water Conservation Division	1978	[4]	175.0
Department of Environment	1980	[5]	95.0
National Wasteland Development Board	1985	[6]	123.0
Society for Promotion of Wastelands Development	1984	[7]	129.6
National Remote Sensing Agency	1985	[8]	53.3
Ministry of Agriculture	1985	[9]	173.6
Ministry of Agriculture	1994	[10]	107.4
NBSS&LUP	1994	[11]	187.7
NBSS&LUP (revised)	2004	[12]	146.8

Fig. 1 extent of land degradation in India, as assessed by different organizations [1]

Soil degradation has become a serious problem in both rainfed and irrigated areas of India. India is losing a huge amount of money from degraded lands (Fig. 2). This cost is documented by declining crop productivity, land use intensity, changing cropping patterns, high input use and declining profit. Reddy [2] valued the loss of production in India at Rupees (Rs) 68 billion in 1988–1989 using the National Remote Sensing Agency (NRSA) dataset. Additional losses resulting from salinization, alkalinization and waterlogging were estimated as Rs 8 billion. Of late, in a comprehensive study made on the impact of water erosion on crop productivity, it was revealed that soil erosion due to water resulted in an annual crop production loss of 13.4 Mt in cereal, oil seeds and pulse crops equivalent to ~US$162 billion [3].

Parameters	NRSA [19]	ARPU [20]	Sehgal and Abrol [21]
Area affected by soil erosion (Mha)	31.5	58.0	166.1
Area affected by salinization, alkalinization and waterlogging (Mha)	3.2	-	21.7
Total area affected by land degradation (Mha)	34.7	58.0	187.7
Cost of soil erosion in lost nutrients (Rs billion)	18.0	33.3	98.3
Cost of soil erosion in lost production (Rs billion)	67.6	124.0	361.0
Cost of salinization, alkalinization and waterloggingin lost production (Rs billion)	7.6	-	87.6
Total direct cost of land degradation (Rs billion)	75.2	-	448.6

Fig. 2 Estimates on the annual cost of land degradation in India [2]

Apart from faulty agricultural activities that led to soil degradation other human-induced land degradation activities include: land clearing and careless management of forests, deforestation, over-grazing, improper management of industrial effluents and wastes, surface, mining, and industrial development. According to Barrett and Hollington (2006)[5], about 10 to 20 million people live on salt-affected land with poor productivity and under alarming ecosystem destruction threats About 6 million hectares of agricultural land become unproductive per year due to various soil degradation processes [6]. The UN Convention on Combating Desertification (UNCCD) held in Brazil in 2012 set a target of zero net land degradation at RioC20, with the goal of reducing the rate of land degradation and encouraging the pace of regeneration of already degraded land [7]. An estimated 120.40 million hectares (out of 328.73 million hectares) of land in the country was impacted by land degradation According to the Indian Council for Agricultural Research (ICAR, 2010), LULC's Change detection studies have proved to be very successful in determining possible adverse environmental impacts. Hence, it becomes essential to devise effective strategies for land management at the landscape level by analyzing the extent of land degradation using model simulation studies for LULC dynamics [8].

Remote sensing data alongside GIS are helpful to map India's desertification process at a scale of 1:500,000 [9].In the above national level analysis, multi season Sentinel data was used. As described above, it's additionally necessary to analysis and perceives whether or not land degradation (area and severity intensity) will increase or decreases over time. Thus the analysis was conducted to work out the changes in the desertification / land degradation status, in terms of degree and magnitude, using IRS data for the Rasulabad block, Kanpur district during a certain time.

A. Land Degradation

Land degradation is the process that makes land unsuitable for human beings as well as for soil ecosystems occurs in arid, semi-arid and sub humid areas as a result of anthropogenic activities and climatic variation and eventually subjects livelihoods and sustainable development to severe risks. Land use and land cover (LULC) change is a prime issue for scientists concerned with global environmental change [10].

Land degradation poses a great threat to food security and damages the environmental safety of land as well as influences the sustainable development of society and economy. Degradation can lead to exhaustion of other natural resources in both developed and developing countries and affect arid, dry and even sub-humid areas. Soil degradation takes place not only as a result of interaction between physico-chemical and biological factors comprising topography, soil properties and climatic but also includes human factors and land use management practices [10].

B. Types Of Degraded Land

1) *Land affected by salinity/alkalinity:* Soil salinity is the salt content in the soil; the process of increasing the salt content is known as salinization. Salts occur naturally within soils and water.
2) *Waterlogged/marshy land:* Water logging is the lowering in land productivity through the rise in groundwater close to the soil surface. Salinization issued in its broad sense, therefore total types of soil degradation brought about by the increase of salts in the soil.
3) *Scrub Land:* Scrubland is plant community with scrub vegetation. "Scrub" means low shrubs, mixed with grasses, herbs, and geophytes. Scrublands are sometimes known as heath lands. Scrub lands may develop naturally or as result to human activity

II. MATERIALS AND METHODS

A. Description Of Study Area

Rasulabad is a Block positioned in Kanpur Dehat district in Uttar Pradesh. Situated in rural area of Kanpur, Uttar Pradesh, lies between 26.6761° N latitude and 79.7778° E longitude. As per the government register, the block code of Rasulabad is 353.The block has 148 villages. As of 2001 India census, Rasulabad had a population of 7235. Males constitute 53% of the population and females 47%. Rasulabad has an average literacy rate of 41%, lower than the national average of 59.5%: male literacy is 49%, and female literacy is 31%. In Rasulabad, 19% of the population is under 6 years of age.

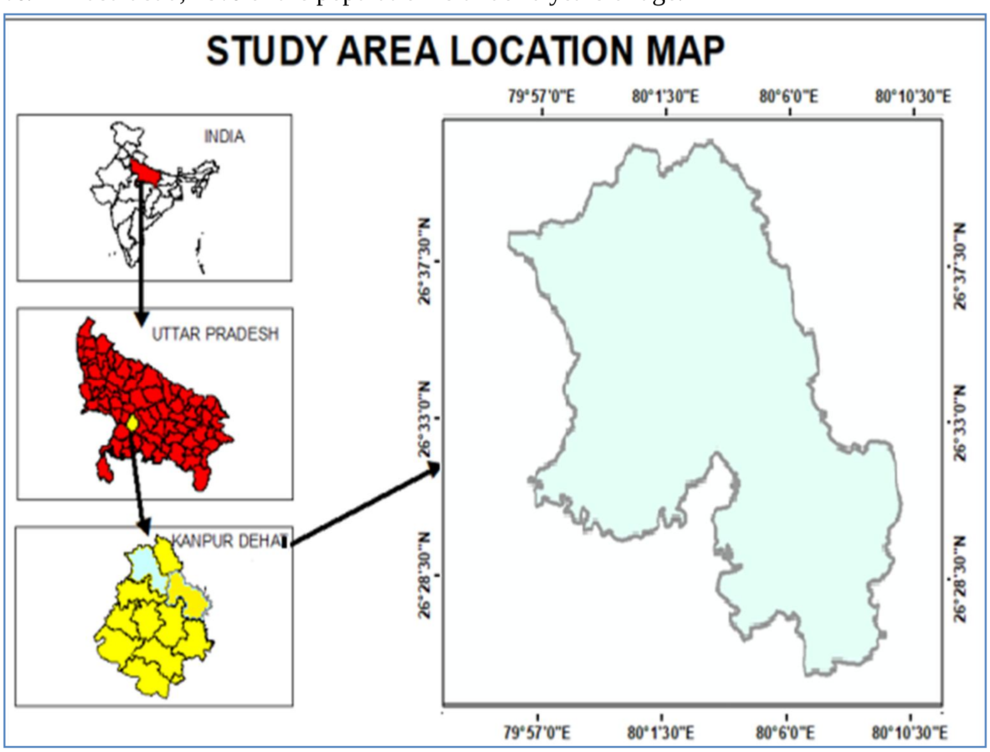


Fig.3 Study area map

B. Data And Software Used

The change detection analysis of land degradation factors which are affecting land area is major aspect for the research. There is much knowledge is required about the land surface for change detection analysis. It needs of data sets of different years for finding the sodic land and saline land by comparative analysis. For this analysis ARCGIS 10.2.2 version software is used.

Table .1 Description of satellite data sets used

SATELLITE	SENTINEL (INDIAN REMOTE SENSING SATELLITE)
SENSOR	SENTINEL
RESOLUTION	10 m
ACQUISITION YEAR	2017-2021
SOURCE	USGS

C. Methodology

Details of the methodology used for mapping desertification and land degradation status, using satellite data is given in Table 1. Two season IRS SENTINEL data pertaining to the years 2017 and 2021 have been used in this study aimed at monitoring the changes in the land degradation status during the certain period. Visual analysis techniques have been employed on the multi-season satellite data to prepare desertification status maps (DSM) for both the data sets. In addition to the DSM, land use/ land cover (LU/LC) map of the study area was prepared, basically, to understand the type and the severity of degradation processes happening vis-à-vis the land use classes in which they occur.

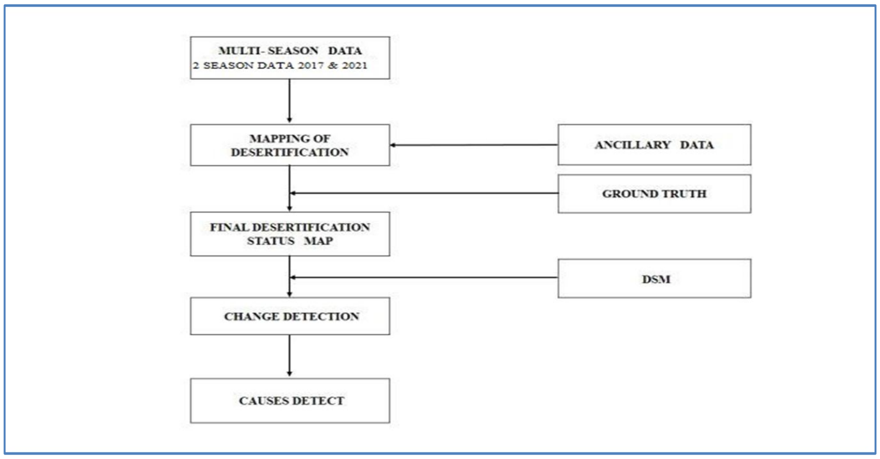


Fig. 4 Methodology for Desertification Status Mapping (DSM)

D. Soil Sampling And Analysis

Soil Sample is collected from different areas of Rasulabad Block. Soil samples were collected with the sampling tag in air free polythene bag with the help of auger and trowel at depth of (0-25 cm). Samples were then dried and sieved for analysis in the laboratory. Different properties like ph, Electrical conductivity, alkalinity etc. are also measured in order to know the soil health.

E. Laboratory Analysis

Three chemical parameters – pH, EC and alkalinity – were analysed for soil samples in the study area as represented in Table 2. The pH was determined in accordance with the procedure of IS: 2720, part 1-1983 in which a pH meter (OaktonPC2700) was used to record the pH in an extract of 1 V 2 of soil or supernatant liquid. The measurement of EC was carried out in accordance
with IS: 14 767-2000 using an EC meter. Alkalinity of the soil samples was measured with the titration method, using 0.05N H_2SO_4, 0.5% methyl red indicator and 0.25% phenolphthalein indicator. Since the carbonates were absent in the solution, it did not turn into pink. It was then titrated until the colour changed from yellow to rose red, indicated as the end point of titration. The concentration of bicarbonates was calculated from the formula as given in Eq. (1).

$HCO^-3\ gL^-1=$

(Normality of H2SO4 *Vol. of H2SO4 *Eq. wt. of HCO^-3)/mL of aliquot taken [Eq.(1)]

F. Digital Soil Mapping Using The IDW Interpolation Method

Digital soil mapping can be used for the prediction of individual soil properties in large areas over space, generating maps in digital format in a rapid, effective, efficient and low cost manner[10]. Severity of land degradation was shown in quantitative terms within the GIS environment using statistical analysis in ArcGIS. There are several interpolation methods such as Kriging [10] and IDW that estimate cell values by averaging the values of sample data points in the neighborhood of each processing cell. For the preparation of soil maps in the present study, IDW was used to estimate the variables pH, EC and alkalinity over space. The IDW (Inverse Distance Weighted) method is a non-geostatistical interpolation method based on the fact that the local impact of a variable gradually disappears with the increase in distance. The methodology incorporates soil scientific knowledge and provides a reliable logical framework to the mapping of continuous surfaces in a quantitative approach.

III. RESULTS AND DISCUSSION

A. LULC MAP OF RASULABAD

Followed by preparation of False Color Composite and visual interpretation, LULC maps of Rasulabad were prepared for 2017 and 2021 as given in Fig. 5(A) and 5(B).

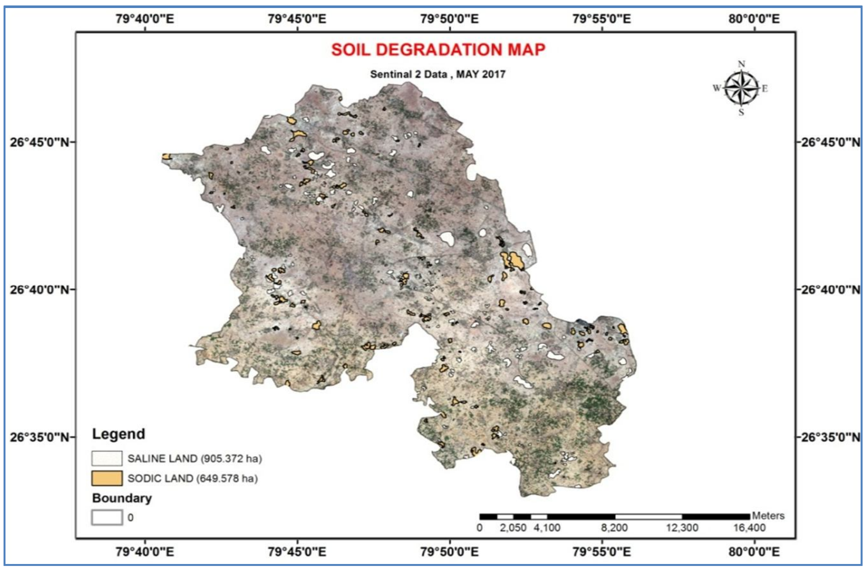


Fig. 5(A): Sodic Land and Saline Land Map of Rasulabad Block Kanpur Dehat U.P 2017

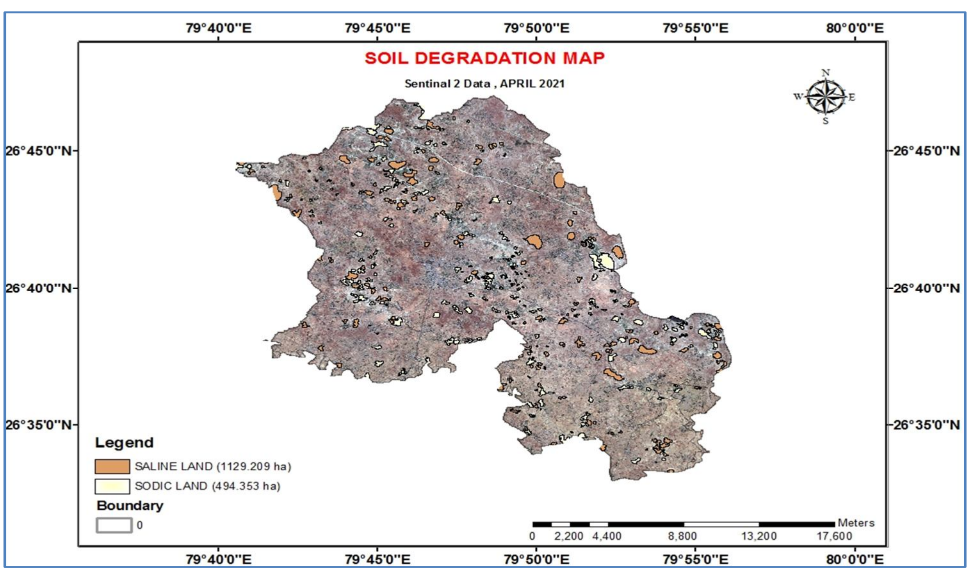


Fig. 5(B): Sodic Land and Saline Land Map of Rasulabad Block Kanpur Dehat U.P 2021

B. Change Detection Analysis

To analyze changes between different land features for a period of 4 years, supervised images of both 2017 and 2021 were used. Land degradation mapping for the year 2017 reveals that salinity/alkalinity of land is the significant desertification process observed in the district which covers almost 32.61 per cent of area of the block. Salinity in the district has increased from 9.0537 km^2 in 2017 to 11.292 km^2 in 2021and sodicity area has decreased from 6.495 km^2 in 2017 to 4.943 km^2 in 2021. Total area undergoing the process of land degradation in the block was 15.549 km^2 in 2017 that has increased to 16.235 km^2 in 2021(about 58.50 % of the geographic area). Comparison of geological process standing maps are prepared from the satellite images of 2017 and 2021 reveals that there's an overall increase within the space below totally different processes of geological process. The that trend within the degree of soil degradation processes might have adverse effects on several soil surface processes connected to geophysical science and erosion and thence it's necessary to require effective combative measures to mitigate or arrest soil degradation processes among the block. The decreased portion depicted the decrease in overall land area under agriculture (with or without crops).

C. Laboratory Analysis For Soil Parameters

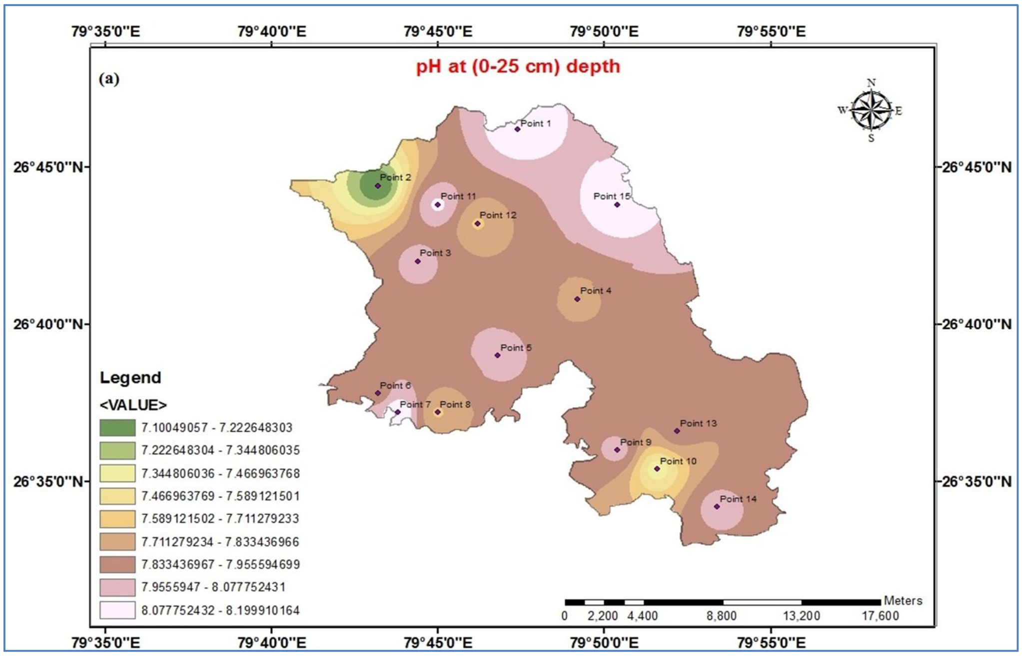
The pH, EC and alkalinity values of the soil samples collected from the sampling sites of the study area are given in Table 2. All 30 soil samples collected from different locations of the study area were mostly alkaline in nature. None of the sampling sites were much acidic. Around 60–70% of soil samples were slightly or moderately saline. The rest of the samples were categorized as salt-free. Alkalinity was then determined with methyl alkalinity, which indicated the presence of bicarbonate ($HCO3^-$) ions. The methyl orange or total alkalinity of soils in the study area was in the range of 0.095 to 0.225 ($HCO3^-$) gL^-1 as CaCO3.

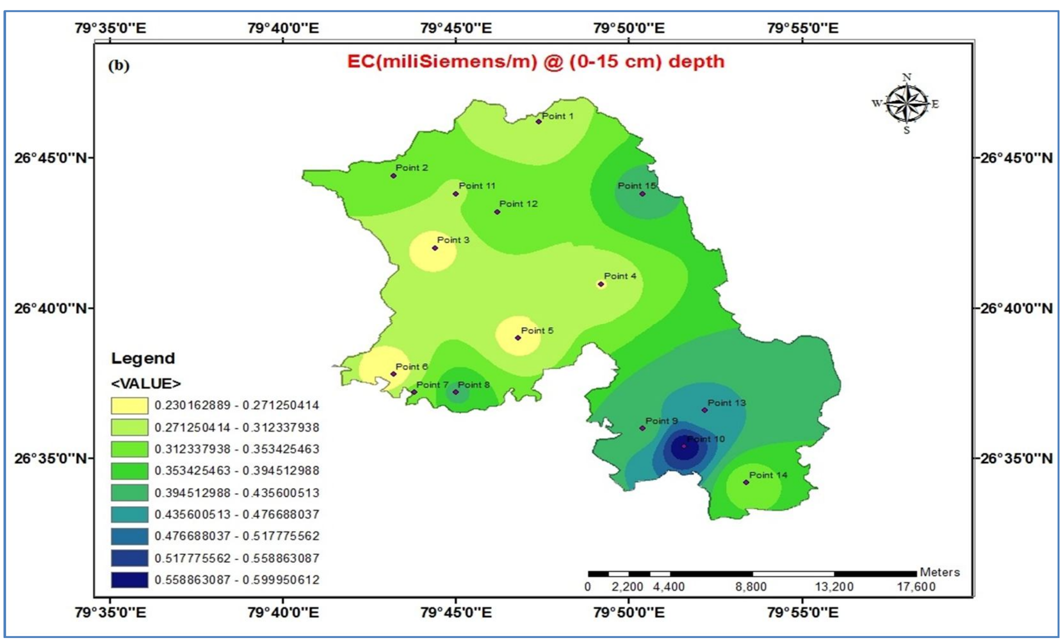
Table. 2 Results Of Various Parameters

Sample points	pH at (0-25 cm) depth	EC(miliSiemens/m) at (0-25 cm) depth	Alkalinity ($HCO3^-$)g L^{-1} as CaCO3
Point 1	8.2	0.28	0.162
Point 2	7.1	0.34	0.141
Point 3	8	0.25	0.154
Point 4	7.8	0.27	0.130
Point 5	8	0.25	0.128
Point 6	7.9	0.23	0.131
Point 7	8.2	0.32	0.122
Point 8	7.7	0.41	0.134
Point 9	8	0.40	0.095
Point 10	7.4	0.6	0.110
Point 11	8.1	0.31	0.137
Point 12	7.7	0.35	0.225
Point 13	7.9	0.44	0.128
Point 14	8	0.32	0.121
Point15	8.2	0.42	0.156

D. Generation of Soil Maps

Digital soil mapping was used for the prediction of spatial variability in individual soil properties in the study area, where maps could be generated in digital format in a rapid, effective, efficient, and low-cost manner [10]. Land degradation severity was shown as spatial distribution of pH, EC and alkalinity in quantitative terms via IDW interpolation methods using the statistical analysis tool in the ArcGIS software. Based on the pH values, a soil map for sampling sites was composed with the ArcGIS 10.2 software (Fig. 6a). Similarly, on the basis of EC and alkalinity values, soil maps were composed as shown in Fig. 6b and c, respectively, depicting the severity of land degradation in terms of salinity. Based on EC values, it could be observed from the map (Fig. 6b) that in the study area, the maximum area was occupied by slightly saline soils, and some of the regions were moderately saline. Only a few of the sites were salt-free. Based on alkalinity, it was observed from the map (Fig. 6c) that most of the study area was less alkaline, ranging between 0.095 and 0.0.225 ($HCO^{-}3$) $gL^{-}1$ as $CaCO^{3}$, But in general, all the sampling sites had a low range of alkalinity.





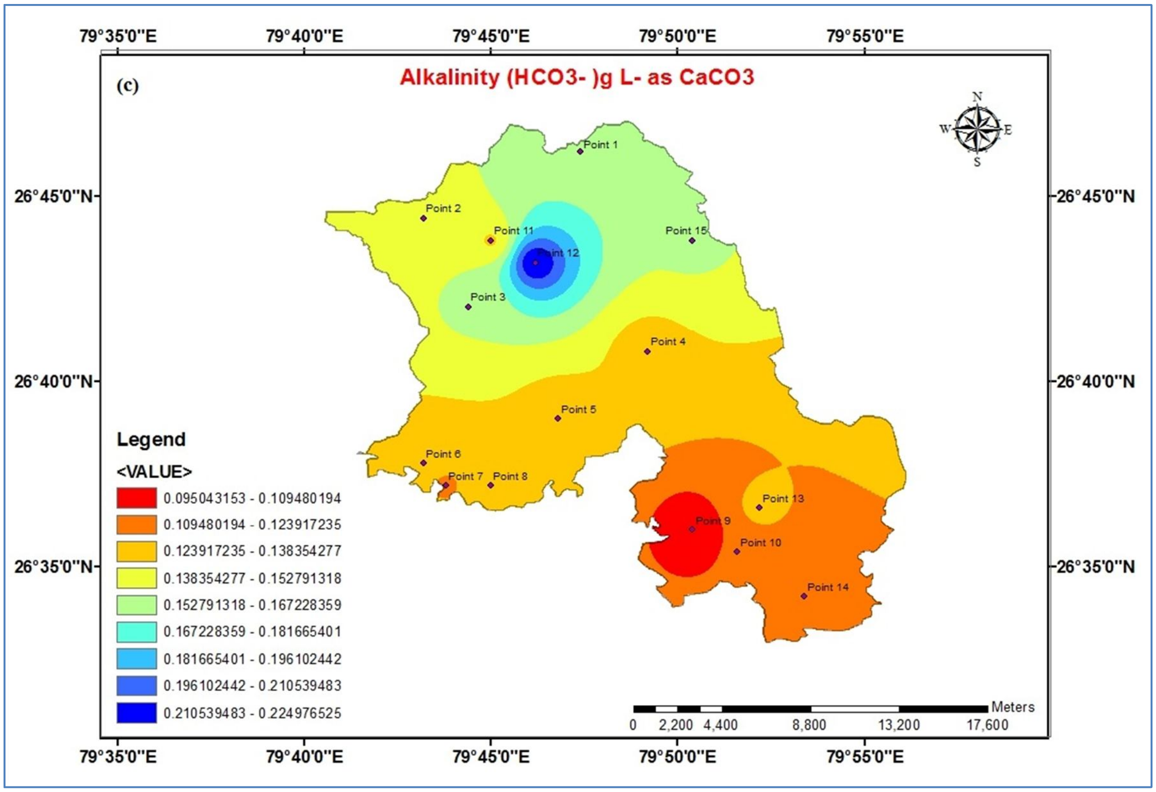


Fig. 6(a): Soil map on the basis of pH values. **(b):** Soil map on the basis of EC values. **(c):** Soil map on the basis of alkalinity values..

IV. CONCLUSIONS

Earth Observation satellite information were accustomed prepare the land degradation standing map (DSM) for Rasulabad block of Kanpur Dehat district of for 2 timeframes 2017 and 2021. These maps are accustomed monitor and assess the method of Land Degradation throughout the bound amount. As per the DSM maps of 2017 and 2021, the area beneath land degradation within the Block has accumulated from 15.549 % to 16.235 %. The main soil degradation processes active within the Rasulabad Block area are salinity / base-forming and soil sodicity. Due to this soil's properties like Ph, EC, alkalinity etc are not in appropriate range. The soil physico-chemical analysis proved to be very useful in assessing the degree of salinization. Most of the regions had calcareous soil with slight to moderate salinity and none of the sampling sites were highly saline. The results show clearly that there is growing increase within the desertification cycle. Cheap steps should be taken to arrest the Block and, if necessary, reverse the geological process. Degradation of the land, livelihoods and environmental conditions area unit inextricably connected. It's thus suggested that action plans for land resource management and land degradation mitigation within the country as an entire be created a vital element of Panchayat-level rural development program. The present study is a useful tool for analysis of environmental sensitivity on a regional scale and the identification of hotspots of land degradation. Although it does not provide a detailed insight into the causes and manifestations of land degradation, this study may help to identify areas vulnerable to land degradation. This would also be helpful to achieve better results with limited investment and avoid wastage of natural resources.

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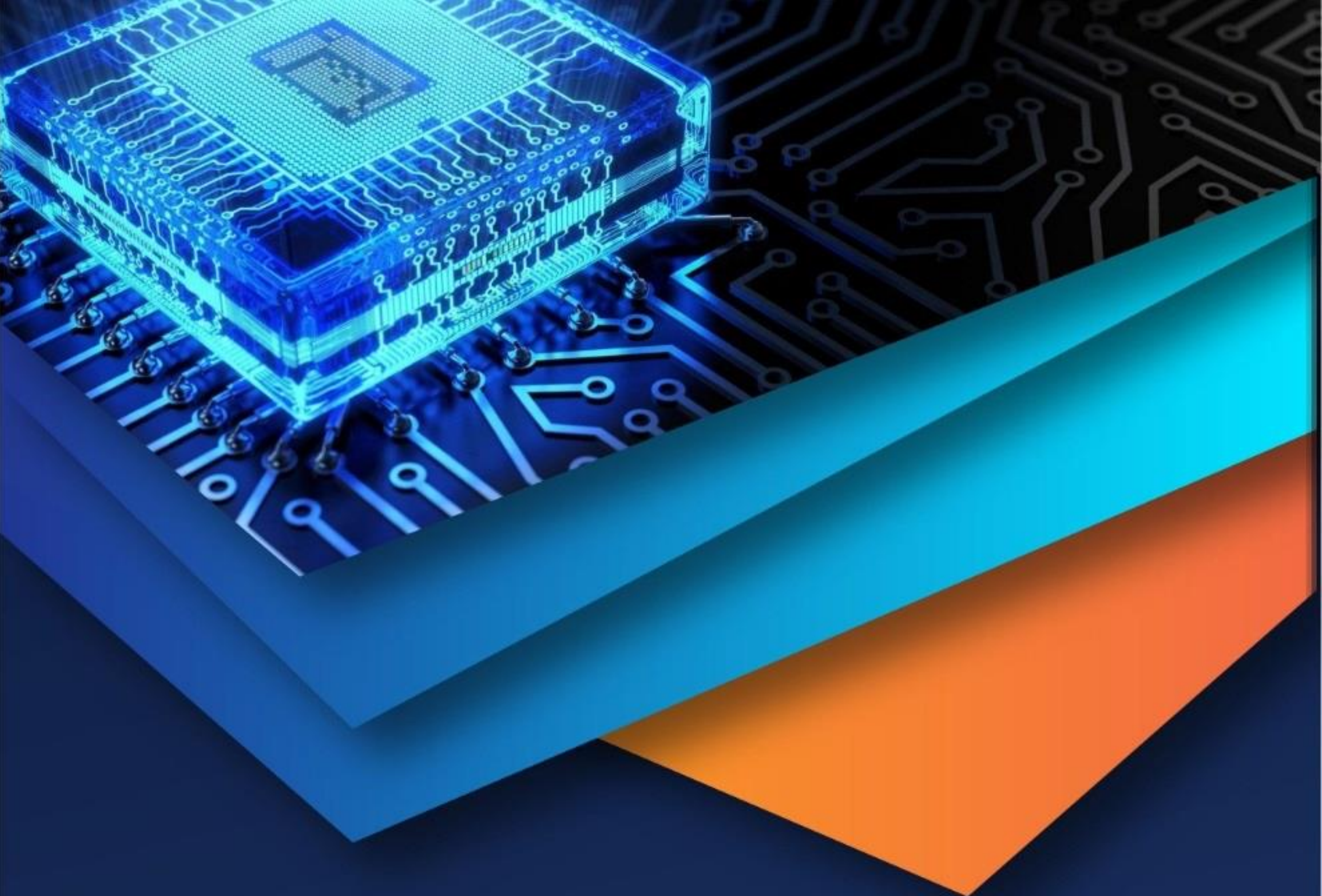

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