

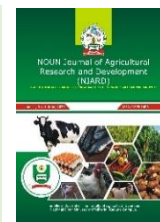


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Original Article

Assessment of Land degradation vulnerability of University Teaching and Research farm, Malete, using geospatial technique



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ABSTRACT

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Vulnerability Assessment of Malete soil to degradation was carried out through the use of spatial techniques. The assessment of physical, chemical, and biological degradation of soils as well as the causes of this degradation is covered. Low inherent fertility status of these soils was found by analysis of chemical and physical parameters. Using satellite data, four main land cover classifications were identified. According to the results of the land cover changes, cropland and water bodies have expanded by 24% (5.3 sq m) and 32% (7.1 sq km), respectively, while fallow land and sparse vegetation have reduced by 20% (4.5 sq km) and 23% (5.2 sq km), respectively. The vulnerability assessment map showed that only the Operation Feed Yourself farm (OFY) block (Red Signature (6.4-7.0%)) has a low sensitivity to land degradation, followed by blocks 3 (Lemon signature (7.5-8.1%)), 4 (Orange signature (7.0-7.5%)), and block 2A (Green signature (8.1-9.0%)). A sustainable, non-degrading agricultural system can be maintained by better planning for soil conservation in high degradation risk locations. There should be more education for farmers about the kind of land they farm. According to the study, land should be given some time to rest so that nutrients can be regained. It is advisable to promote the usage of organic or animal matter as a natural fertilizer. Planting grasses and leguminous plants will improve the soil's fertility in the area. This is true because it always costs more to restore damaged soil or land to its original productive usage than it does to stop it from happening in the first place.

Keywords: Land degradation, Soil conservation, soil fertility, spatial techniques, vulnerability assessment



1.0 INTRODUCTION

There are various methods to define land degradation depending on the point that needs to be made. Wasson (1987) described it as a change to land that renders it less valuable for humans. According to a more precise definition, land degradation is the decline in soil's ability to perform at its peak in ecosystems (Kimpe and Warkentin, 1998). The term "land degradation" describes the temporary or long-term decline in the land's ability to produce goods and services as a result of human activity. One of the biggest environmental problems that affect both industrialized and developing nations is land degradation (Bai *et al.* 2011).

The impacts of this environmental issue, which has a gradual beginning and is the result of both natural and human influences, are cumulative (Eswaran *et al.*, 2001; Bai *et al.* 2011; UNFCCC 2012).

The susceptibility of a region to degradation as determined by the many causes of loss of productivity is known as vulnerability to land degradation. But in low-income nations where agriculture provides the majority of people's livelihood, its severity and consequences are far more acute (Daniela *et al.*, 2022).

Before being turned over to the university and used as a teaching and research farm, Kwara State University's Teaching and Research farm had been subject to intensive farming by the local peasant farmers. As a result, it is believed to be highly vulnerable to degradation because human activity makes land degradation in agricultural areas worse.

The farm occupies a broad area of around 100 hectares; due to this size, a substantial amount of data must be processed, which may be done with the help of widely used Geographic Information Systems (GIS). The capacity of GIS to store and display data spatially aids in data management, data analysis, and can be used as an interface for the assessment of land degradation (Obasi *et al.*, 2011).

According to Tiani *et al.* (2015), vulnerability is a dynamic process that changes as the condition of a system component changes. As a result, in order to make the proper measurements for resource conservation, vulnerability to land degradation must be continuously examined.

As a result, the purpose of this study is to evaluate the susceptibility to land degradation at the Teaching and Research Farm in Malete by combining GIS, Remote sensing (RS), and multicriteria analysis. The study's more specific objectives include mapping the geographical and temporal changes in land use and land cover, determining the risk of soil erosion, and creating a land degradation vulnerability index for Malete soils using spatial multicriteria analysis. Therefore, this study would encourage local efforts to improve natural resource management, as well as contribute to literature on the topic of land degradation.

2.0 MATERIALS AND METHODS

2.1 Site description

The experimental site is located at Teaching and Research farm in Moro Local Government Area of Kwara State University, Malete, Kwara State, Nigeria. It lies between latitudes 8° 41' 59" N to 8° 71' N and longitudes 4° 28' 0" E to 4° 44' E at 365m above sea level. The Kwara State University Teaching and Research Farm, Malete consists of approximately 100 hectares. It consists of the farm centre and area for the teaching and research activities of the Department of crop production, Agricultural Economics and Extension Services, Animal production, Fisheries and Aquaculture. The study evaluated soil categorization and characterization made from Alfisols, a basement complex rock, Gambari series (Alabi *et al.*, 2017). Application of remote sensing and geographic information system (GIS) were used in identification, interpretation, classification and mapping of the studied soils.

2.2 Data acquisition

In order to evaluate the research field, Ancillary data, such as soil nutrient characteristics, remote sensing data, including landSat 8 Enhanced Thematic Mapper (+ETM) of year 2010 and 2019 with 30-meter resolution (Figure 11), and Global Land Cover Facility (GLCF) and U.S. Geological Survey Data, were downloaded from the Earth Science Data Interface (ESDI) website (USGS). After ground-truthing, Google Earth Imagery was used to support and validate the collected LandSat 8 +ETM. Pan-sharpening was used to construct the LandSat 8 data sets using their 15-meter panchromatic band. Before being transferred to ArcGIS 10.5 software for image visualization and other processing, the LandSat 8+ETM image underwent image improvement and classification in the Environmental Visual software (Envi) 5.1 environment.

2.3 Image enhancement and classification

In order to identify and categorize land use and land cover information classes from the study area as well as to distinguish spectral properties, image enhancement using LandSat 8+ETM was carried out.

For image enhancement, false colors composite and pre-processing were utilized. In the Envi 5.1 software environment, supervised classification algorithms were utilized.

The image was divided into its many classes using the maximum likelihood classification algorithm, which had a convergence of 0.95 and a maximum number of 20 iterations.

Farmland, scant vegetation, waterbodies, and fallow land were the Areas of Interest (AOI) identified. Map creation, reprojection, and overlaying field data were done using Arc GIS 10.5 while object-based image analysis was done with ENVI 5.1.



2.4 Methods of assessing land degradation

2.4.1 Ancillary data

A Landsat satellite image of the subject area was obtained from 2010 to 2019 for the purpose of this investigation. All were acquired via the Earth Science Data Interface known as Global Land Cover Facility (GLCF). Malet has a pixel size of 28.5 meters and is projected using the Universal Transverse Mercator method in zone 31N of the WGS84 coordinate system. The band combinations used for this study were 4, 3, and 2 (RGB). The remotely sensed data were used to derive information or features about land usage and land cover. The base map and soil maps were created using the topographic map of the study area. Using an overlay modeling technique based on grid-cells, the ground control points were superimposed.

2.4.2 GIS and remote sensing assessment

The ancillary data were assessed in ArcGIS 10.5 and ENVI 5.1. These include topographic maps (1:50,000), remote sensing imageries such as Shuttle Radar Topographic Mapper and Google Earth image of year 2019. The topographic map was digitized in order to extract some features such as road, river and some settlement while the Google Earth were used to identify features for adequate classification. Satellite imagery and topographic map information are integrated to prepare the base map for the study area. Thereafter, digital terrain and contour map are generated from shuttle Radar topographic mapper (SRTM) of 90-meter resolution which guide in soil unit identification. The land use and land cover of year 2010 to 2019 of the study area were assessed in Envi 5.2 remote sensing using LandsAT enhanced thematic mapper, supervised classification algorithm of maximum classification algorithm and region of interest (ROI) was used to identify land use and land cover features of the study.

2.5 Soil mapping

To cover the whole representative area chosen for the study, samples from the study area were taken using rigid grid sampling. An investigation was conducted to have a general understanding of the studied region. Following the reconnaissance, soil samples were taken on the main types of encountered terrain at intervals of

100 m using a soil auger. A 3 hectare area was mapped at each of the chosen sites.

Soil samples from the surface (0–20 cm) and below (20–40 cm) were collected into clearly labeled polyethylene bags, which were subsequently processed in the lab after air-drying at room temperature. For the purpose of growing arable crops, surface soil samples were employed. The coordinates of each soil sampling spot were recorded.

2.6 Laboratory analysis

The soil parameters that were determined include: Particle size analysis, Total nitrogen, Organic carbon, Available Potassium, Phosphorus, Cation Exchanged Capacity, bulk density and soil pH. The particle size was determined by hydrometer method (Bouyoucos, 1962). Total N was determined calorimetrically. Available P was determined by Bray 1 method (Anderson and Ingram, 1993). Soil organic matter was determined by dichromate oxidation procedure (Walkley and Black, 1934). Exchangeable bases (Ca, Mg, K, and Na) were extracted. Soil pH was determined in a 1:2 soil to water suspension using a pH meter (Maclean, 1982). Bulk density (BD) was determined by core method.

3.0 RESULTS

3.1 Physical and chemical properties of soils of the study area

The textural class of soil is sandy soil across blocks. The contents of Nitrogen, organic matter, cation exchange capacity ranges from low to moderate (Table 1). Soil reaction ranged from moderately acidic to slightly acidic (pH 5.47-6.31) with low organic carbon (0.47 - 0.81 %) and available nitrogen (0.042-0.2 %). All exchangeable cations, available phosphorus, CEC were very low. The available Phosphorus were low for all blocks (ranging between 4.54 -9.2 ppm). The percentage Base saturation of the soils was consistently higher than 90 %. It ranged from 92.0 -97.5 %.The low CEC of these soils coupled with low organic matter, low total Nitrogen and available Phosphorus are indications of low inherent soil fertility status across blocks, which under scored the need for improved soil management techniques. All deficient nutrients are Macro nutrients which are needed in large quantities by plants especially in the production of maize. The varied ranges of some mineral elements across blocks are shown in Figure 1, 2 and 3.



Table 1. Physical and Chemical Properties of soils of study area.

Block	Dept (cm)	pH (H ₂ O)	OC %	N %	P (ppm)	K (cmol/kg)	Mg (cmol/kg)	Ca (cmol/kg)	% Sand	% Silt	% Clay	ECEC (Cmol/kg)
2A	0-20	5.72	0.65	0.04	6.37	0.003	0.15	0.75	92	6	2	1.06
	20-40	5.51	0.49	0.04	4.54	0.003	0.05	0.75	92	5	3	0.93
2B	0-20	5.13	0.59	0.05	7.19	0.003	0.05	0.75	93	6	1	0.9
	20-40	5.4	0.55	0.04	6.87	0.003	0.05	0.75	92	7	1	0.8
3	0-20	5.76	0.92	0.05	9.2	0.003	0.20	0.75	94	5	1	1.05
	20-40	5.52	0.63	0.03	8.32	0.003	0.05	0.75	94	5	1	0.92
4	0-20	5.54	0.73	0.05	5.61	0.003	0.15	0.75	93	6	1	1.02
	20-40	5.72	0.47	0.04	5.54	0.003	0.05	0.75	92	7	1	0.9
OFY	0-20	5.53	0.81	0.047	5.42	0.003	0.05	1.15	97	2	1	1.3
	20-40	5.58	0.73	0.039	4.98	0.003	0.05	0.92	97	2	1	1.1

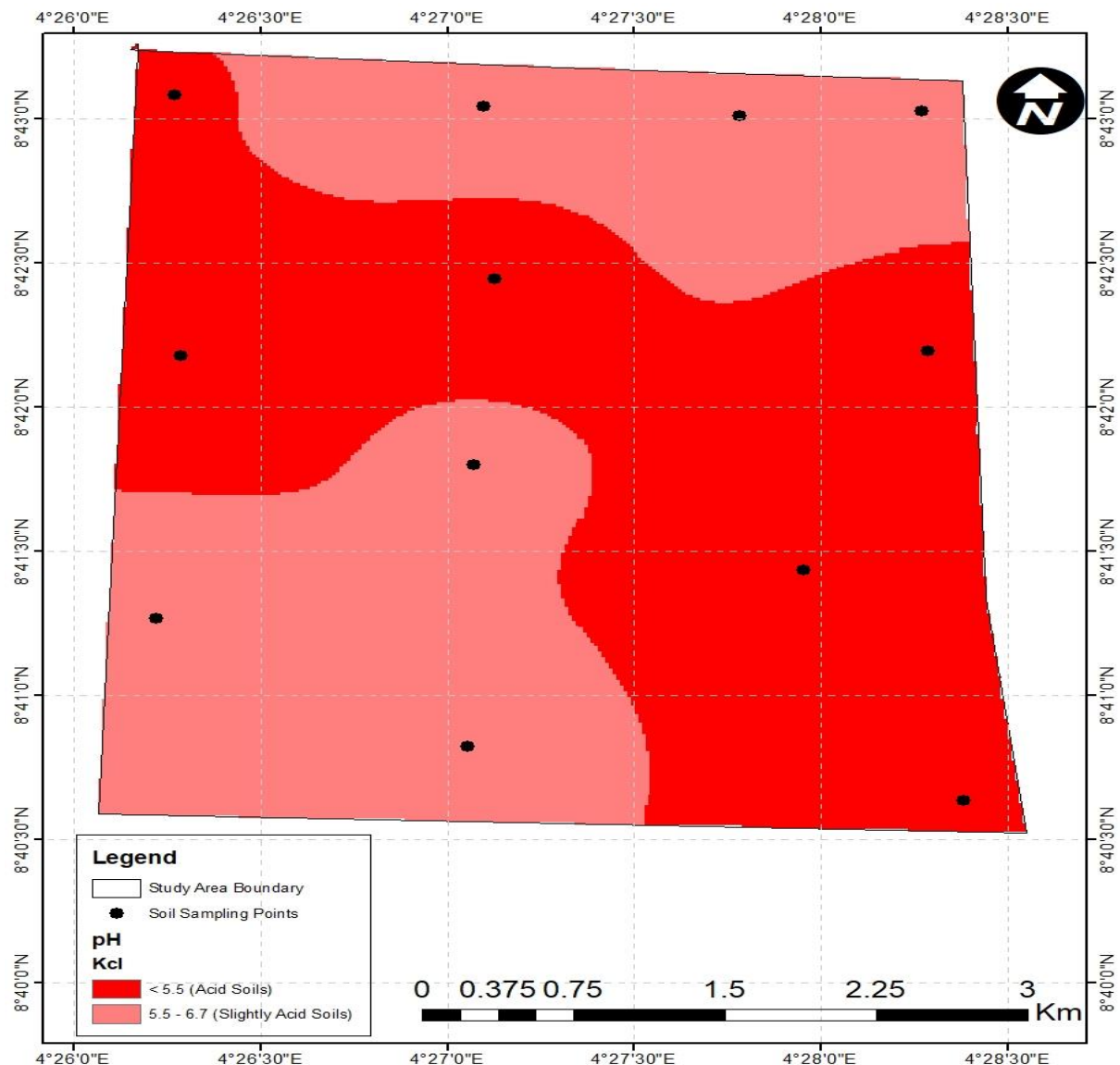


Figure 1. Status of soil pH of study area in year 2020.

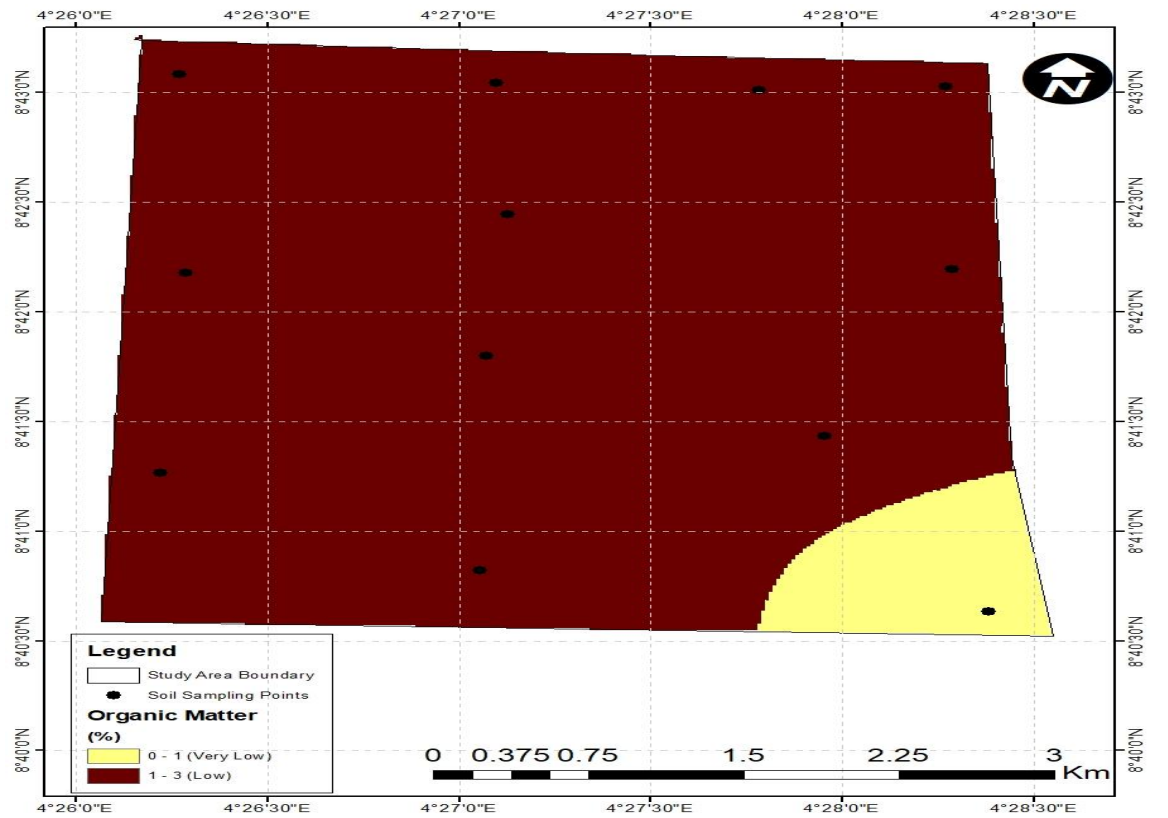


Figure 2. Soil organic matter on nutrient status of the study area in year 2020.

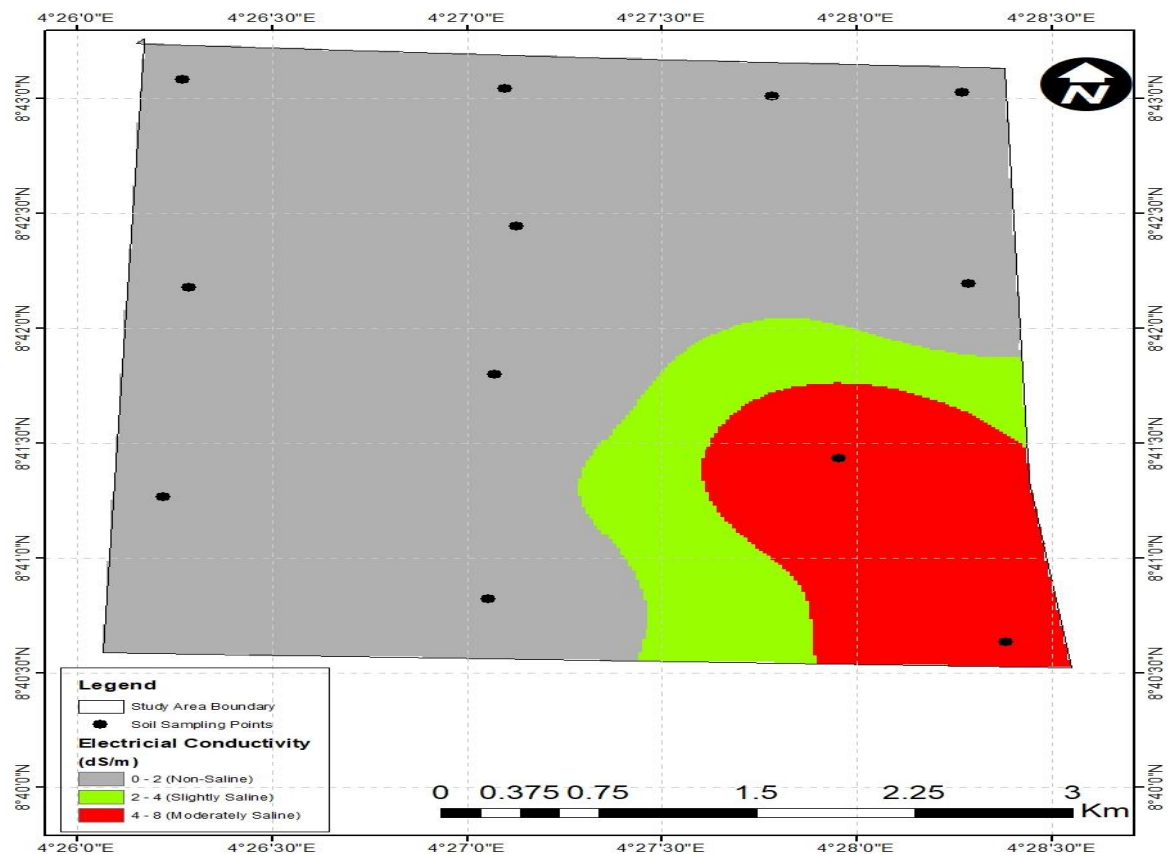


Figure 3. Electrical conductivity status of study area in year 2020.

3.2 Land use and land cover assessment of the study area

Changes in land use and land cover have a substantial impact on the environment on a local, regional, and international level. At both the regional and global levels, these changes have significant effects on the loss of biodiversity worldwide, the functioning of hydrological cycles, the acceleration of soil erosion, and the susceptibility of soil to degradation. Using satellite data, the four main land cover classifications of farming, waterbodies, vegetation, and

and fallow were identified. According to the results of the changes in land cover (Figures 4, 5, and 6), cropland and waterbodies have expanded by 24% (5.3 sq m) and 32% (7.1 sq km), respectively, while fallow land and sparse vegetation have reduced by 20% (4.5 sq km) and 23% (5.2 sq km), respectively.

Anthropogenic activities in the examined area can be blamed for the rise in waterbodies and agriculture and the observed decline in flora. The estimate of land use and land cover is shown in figures 4 and 5 below.

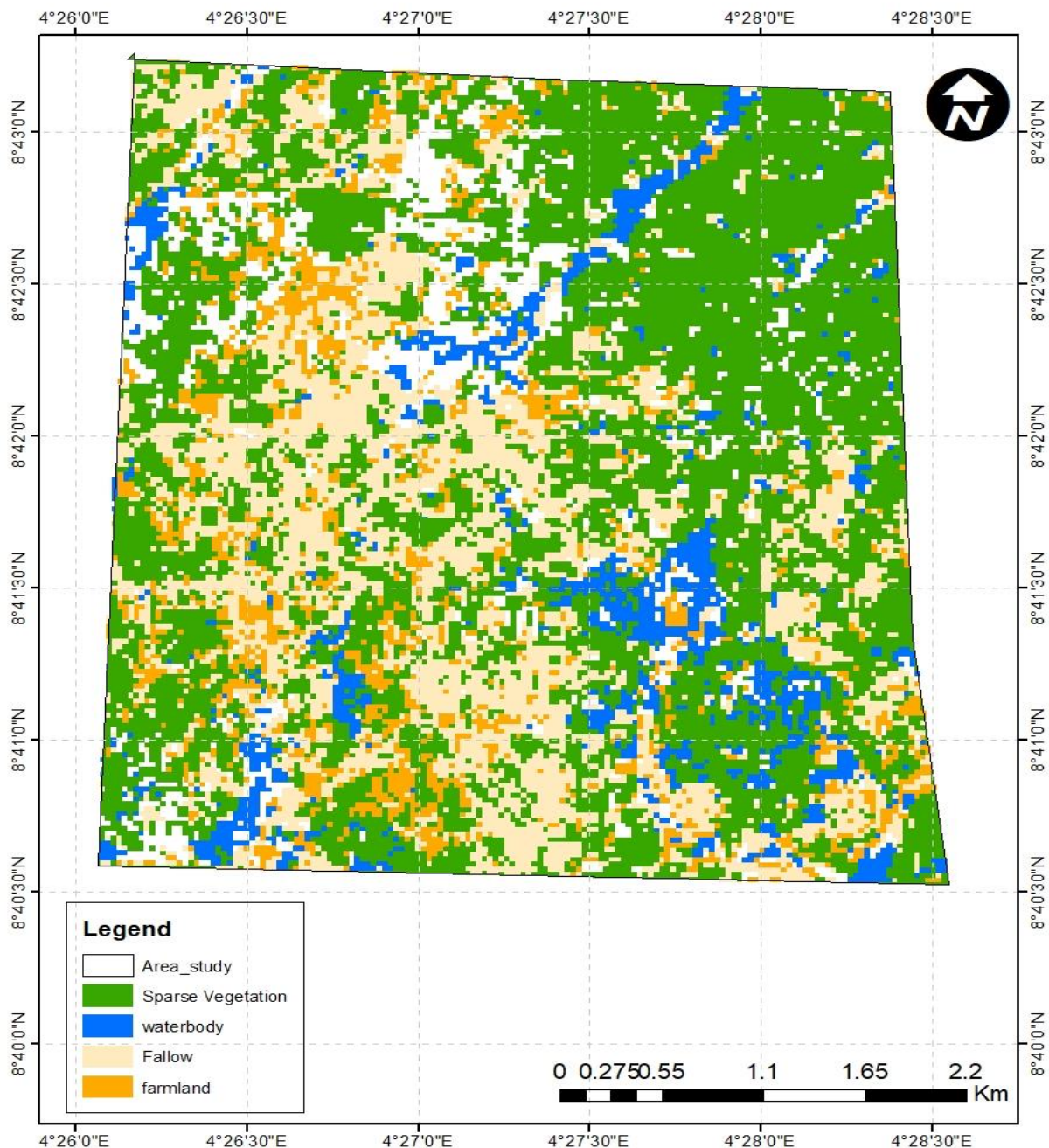


Figure 4. Land use and land cover for the year 2010

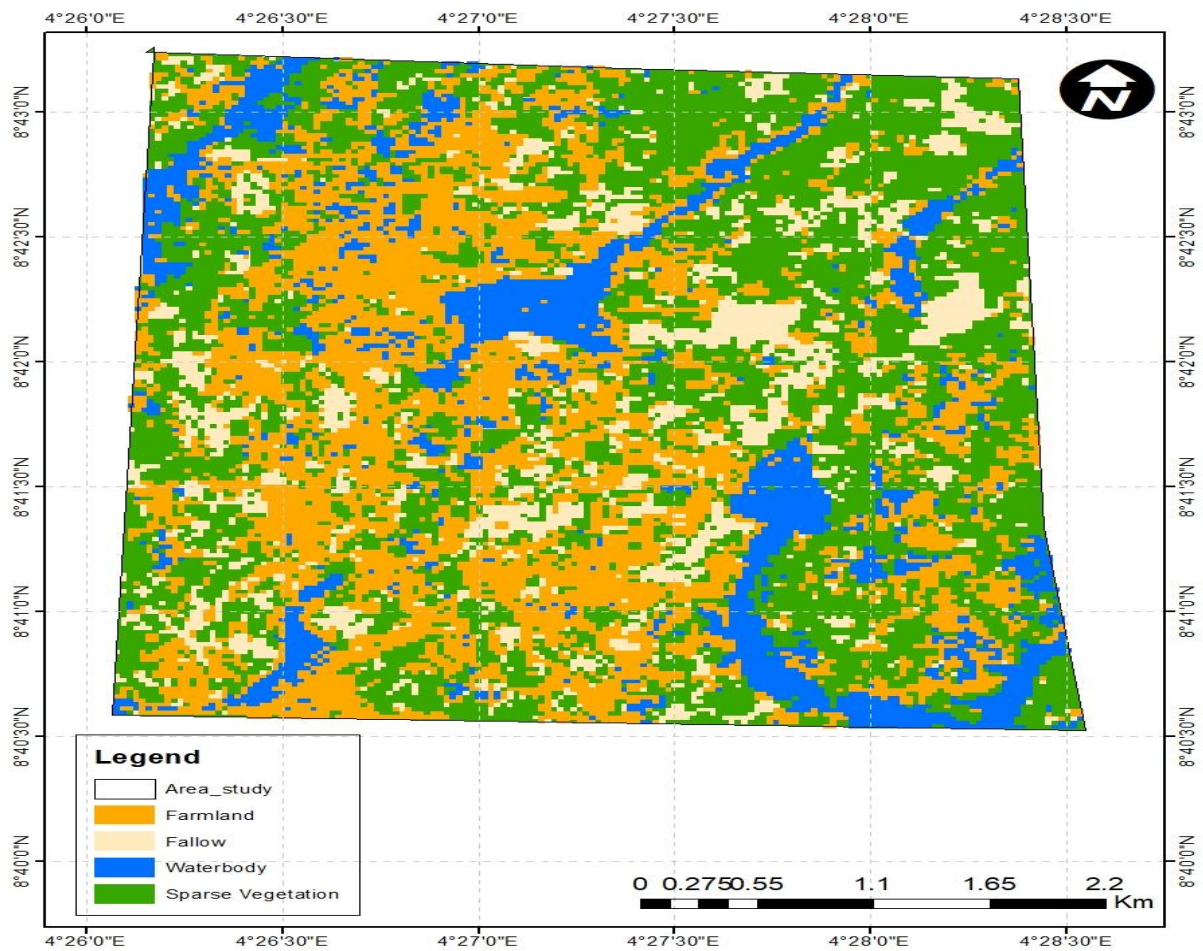


Figure 5. Land use and land cover for the year 2019.

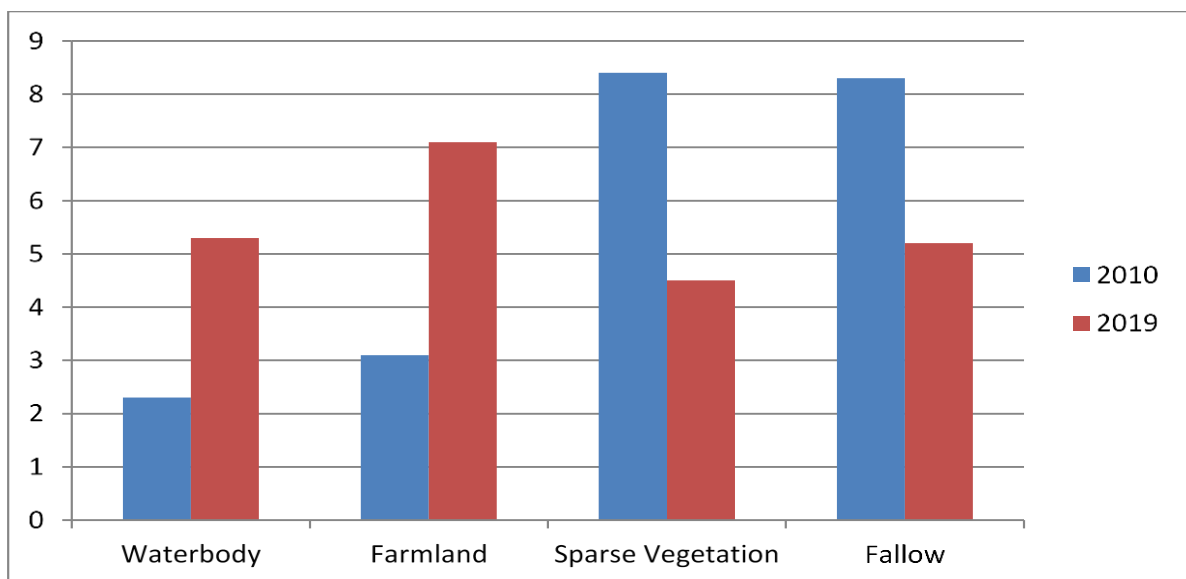


Figure 6. Chart showing waterbody, farmland, sparse, vegetation, and fallow between 2010-2019.

3.3 Soil vulnerability assessment of the study area

In this study, the vulnerability rate was examined using a geo-statistical model (GM) and a geographic information system (GIS) as the decision support system (DSS) (Figure 10). The slope of the area was also evaluated in order to see the undulation of the terrain.

Classes that were identified were barren ground, trees/forest cover, agricultural land, aquatic bodies, and built-up and populated places. Each and every pixel's spectral pattern from the multispectral data

was used to classify and categorize the data on a numerical basis (Lillesand and Kiefer, 1994).

The soil vulnerability degradation of the teaching and research farm soils in Maleté was evaluated using chemical soil degradation. Chemical degradation of a soil refers to unfavorable changes in soil chemistry that result in a deterioration in soil quality as a result of human activity. Soil acidity and losses of organic matter are the two most significant chemical degradation vulnerability indicators. Soil organic matter, soil pH, and electrical conductivity (Figures 7, 8, and 9) were used in this investigation as chemical degradation indicators.

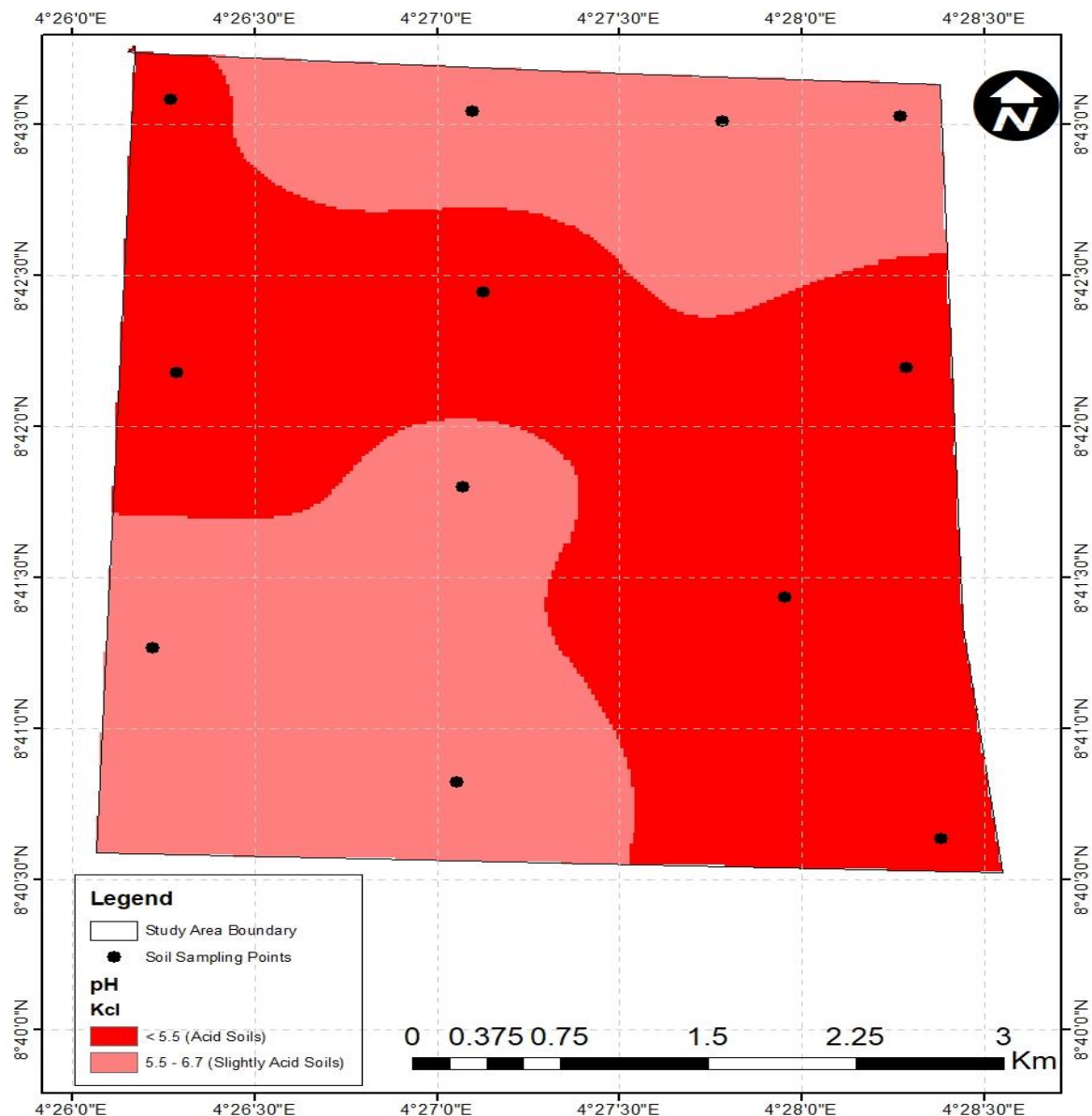


Figure 7. Status of soil pH of study area in year 2020

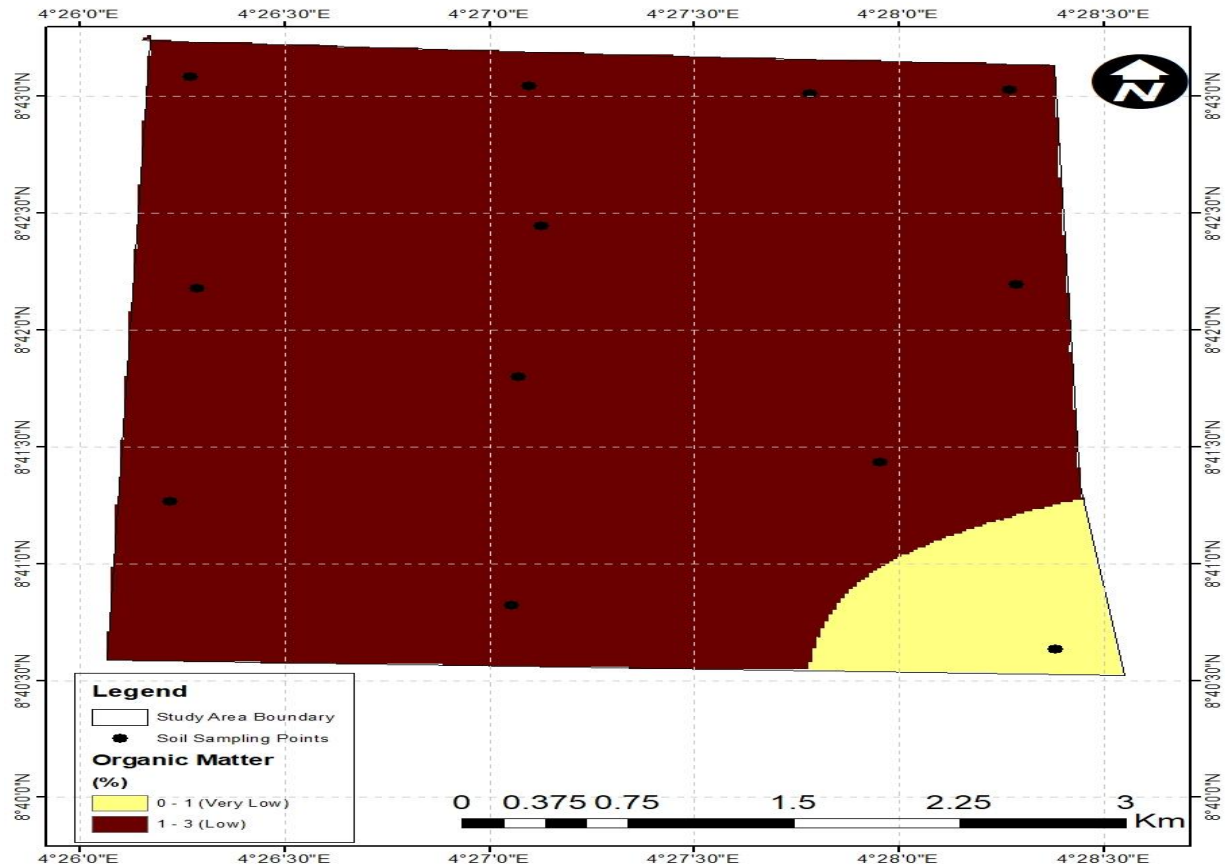


Figure 8. Soil organic matter on nutrient status of the study area in year 2020

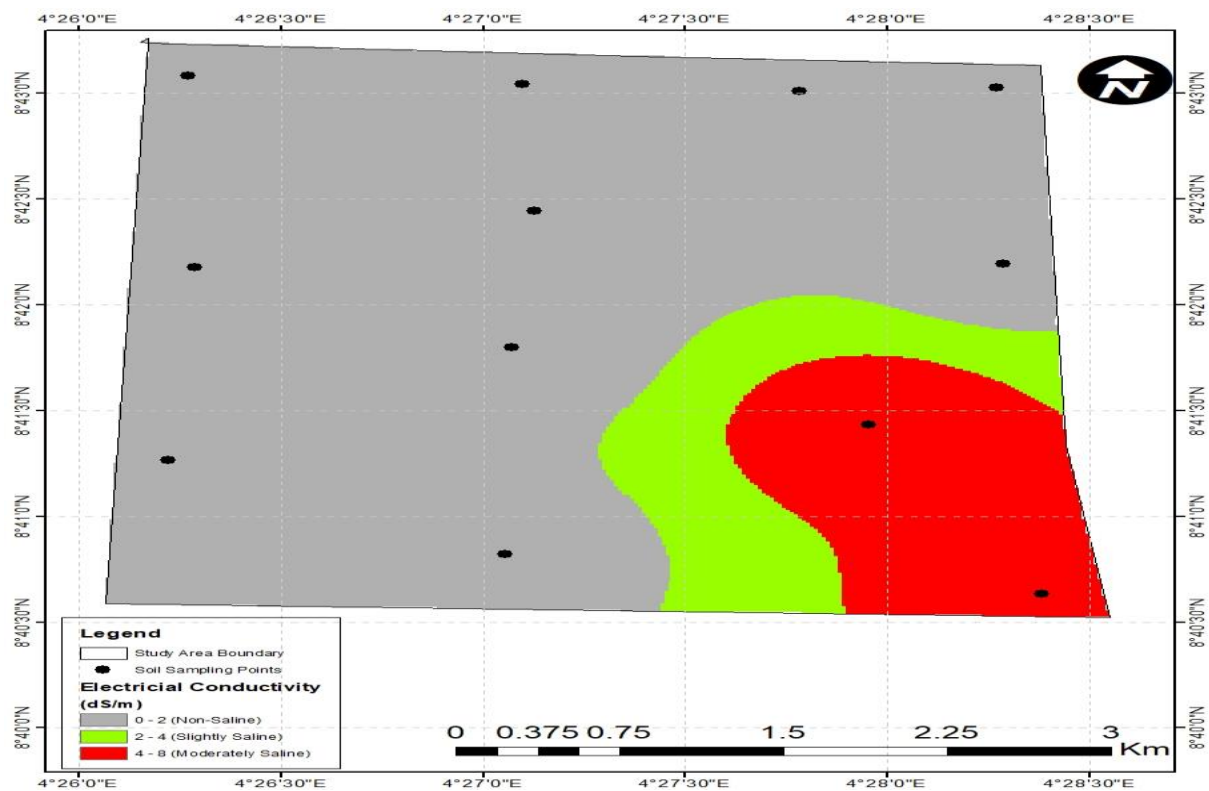


Figure 9. Electrical conductivity status of study area in year 2020.

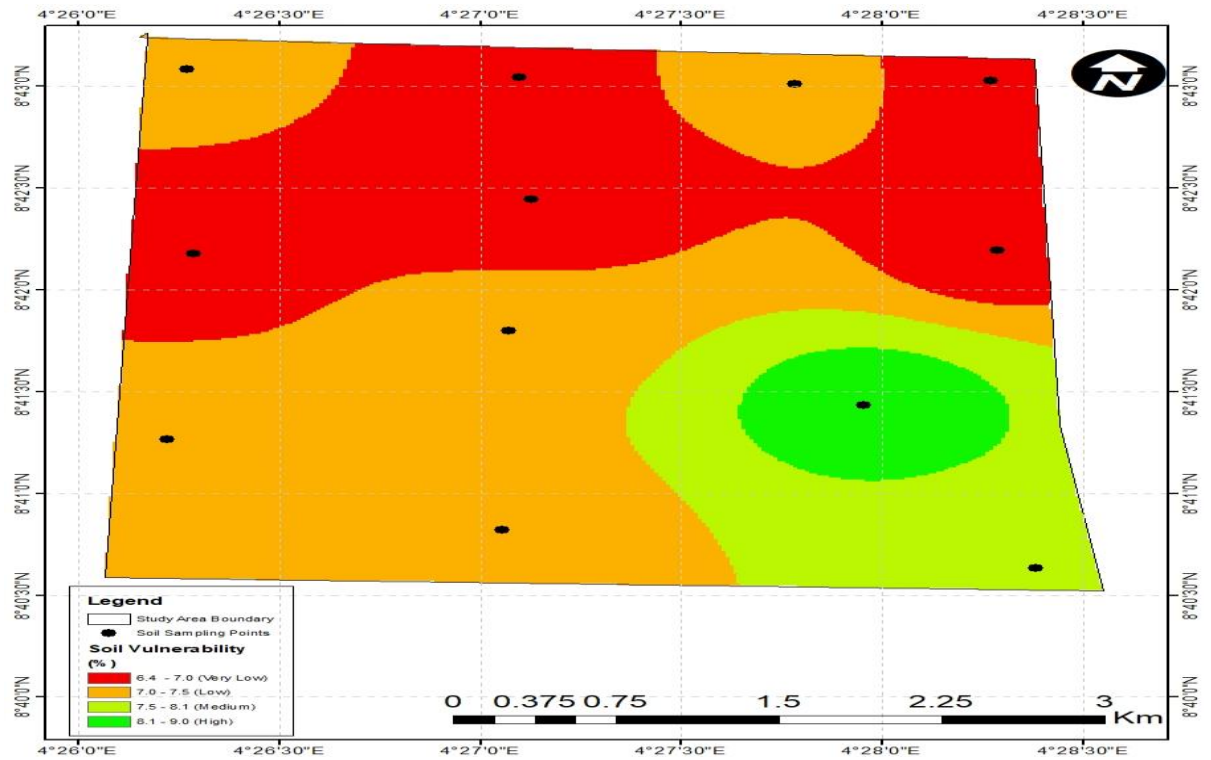


Figure 10. Soil vulnerability assessment of the study area in year 2020.

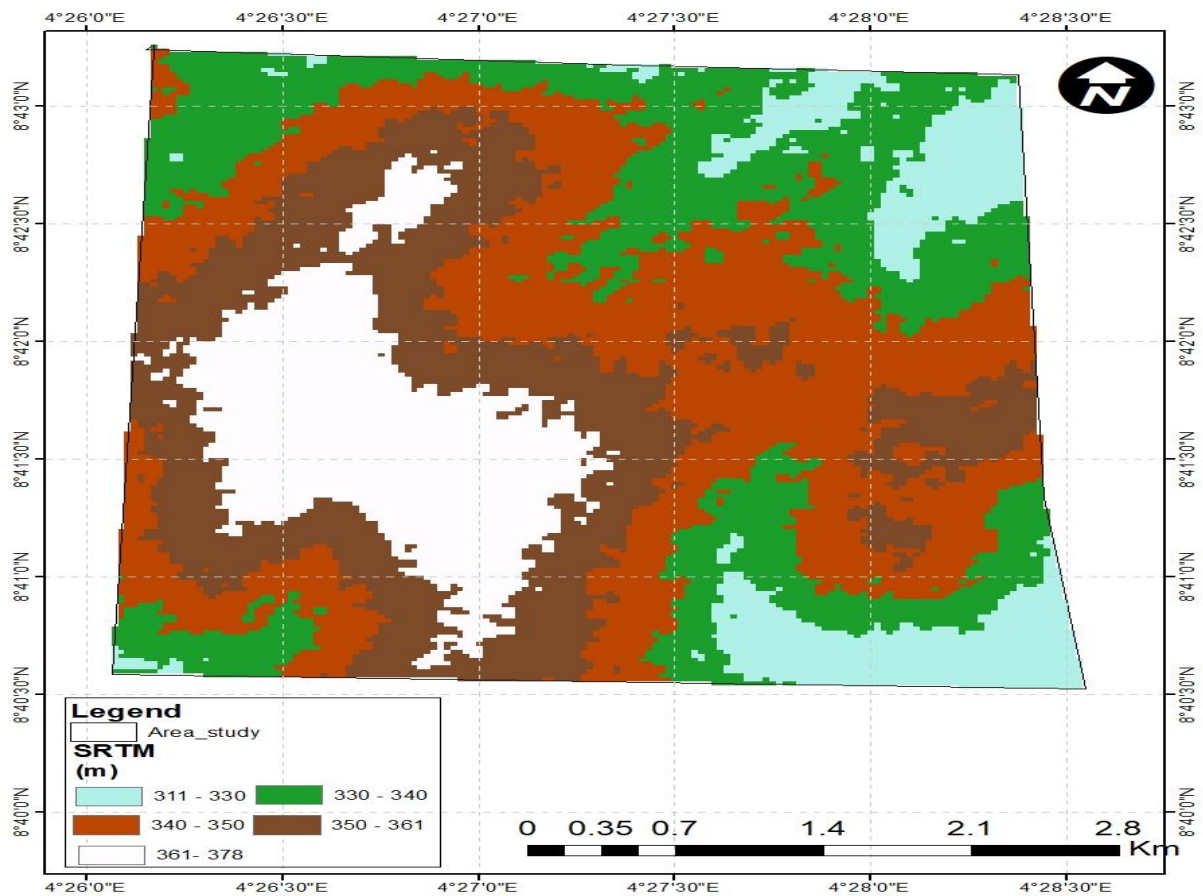


Figure 11. Shuttle Radar Topographic mapper showing the elevation of the study area.

4.0 DISCUSSION

The physical and chemical properties of the study area's soils found that the macronutrients, which plants notably need in high amounts for maize production, are insufficient. These soils' low CEC, along with their low levels of organic matter, total nitrogen, and available phosphorus, are indicators of the blocks' low inherent soil fertility status, and this conclusion was consistent with that of Alabi *et al.* (2017).

Aerial photographs or satellite images of a Maletе maize field were utilized in the detection investigation to access changes in the landscape brought on by anthropogenic activities on the land. It is vital to take into account the changes and interactions between human activities and natural phenomena in order to comprehend landscape patterns for proper land management and decision-making improvements (Tekwa, *et al.*, 2010).

For the purpose of compiling LULC inventories and tracking long-term land change, change detection using remote sensing has shown to be a practical and affordable technique (Coppin *et al.*, 2004; Fry *et al.*, 2011). According to the study's findings, the percentage of land that is under water increased from 2.3 to 5.3, while farmland increased from 15.26 km² in 2010 to 68.98 km² in 2019. Conversely, the capacity of sparse vegetation decreased from 8.4 to 4.5, and the capacity of fallow land decreased from 8.3 to 5.2. This might be a result of built-up areas and settlement growth.

This study is consistent with Silambarasan *et al.*, (2014) in mapping and land use change detection work in and around Udupi Town, which used remote sensing and detected changes partially as a result of more vegetation.

Humans are impacted by the exposure of forest ecosystems and the detrimental effects of habitat degradation within the forest ecosystem caused by the spread of human settlement on agricultural and forest land (Stimson *et al.*, 2005).

5.0 Conclusion

Land is essential to human survival since it provides for all of his requirements, including food, clothes, and shelter. The primary resource for agriculture, raw materials, habitation, and fundamental infrastructure is land.

Due to all of these factors, maintaining the land and preventing its degradation becomes absolutely crucial. Therefore, using multi-temporal, multi-sensor, and multi-spectral remote sensing data in a GIS framework to estimate the level of land degradation will aid in making wise decisions regarding the repair of degraded lands and the conservation of natural resources. The current study is a useful tool for analyzing regional environmental sensitivity and locating areas of rapid land degradation.

The practice of zero or minimal tillage is advised as heavy mechanized land preparation will increase structural destruction. It has been observed that soil nutrient depletion due to poor farming practices and exposure of naked soil through the use of heavy equipment during land clearing for cultivation are the major causes of susceptibility/vulnerability of maize farms, Maletе to degradation.

According to the study's findings, University Maize Farm in Maletе, Kwara State, has a very high frequency of climate risk susceptibility. The following solutions and best practices are suggested due to the shortcomings and limitations of the current solutions. Land should be allowed to rest to build up nutrients again. It is advisable to promote the usage of organic or animal matter as a natural fertilizer. Grasses and leguminous plants should be planted to increase the fertility of the soil in such area.

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