ARDHI UNIVERSITY

OPTIMIZING SUGARCANE PRODUCTION THROUGH REMOTE SENSING BASED SOIL PH CHARACTERIZATION.

CASE STUDY: MBIGIRI ESTATES

BY

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A Dissertation Submitted in the department of Geospatial Science and Technology in Partial Fulfilment of the Requirements for the award of Bachelor of Science Degree in Geographical Information Systems and Remote Sensing (BSc. GIS&RS) at Ardhi University.

CERTIFICATION

The undersigned certify that they have supervised and proof read the dissertation and recommend for acceptance by the Ardhi University a dissertation document entitled "Optimizing Sugarcane Production Through Remote Sensing Based Soil Ph Characterization". In fulfilment of the requirements for the Bachelor of Science degree in Geographical Information Systems and Remote Sensing

Dr. Hayola Joseph	Mr. Maziku Joseph
(Supervisor)	(Supervisor)
Date………………………………	Date……………………………

DECLRATION AND COPYRIGHT

I, Lukumay Agnes M, declare that the contents of this dissertation are the results of my own findings, obtained through studies and investigations. For the best of my knowledge I have, it has not been presented to any other university as a thesis for an award of Diploma, Degree or similar professional award.

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LUKUMAY AGNES M,

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DATE

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DEDICATION

I dedicate this dissertation to my beloved mother for her support and encouragement during every challenges of the university and life as well. I also dedicate this dissertation to my sisters Evaline Lukumay, Rahel Lukumay, Diana Lukumay and my late sister Jackeline Lukumay for their support, advise and encouragement and all those who encouraged me to make sure that I accomplish what I have started. I am truly thankful I have you in my life. My love for you all can never be quantified. God bless you

ABSTRACT

This study aims to optimize sugarcane production through remote sensing-based soil pH characterization, focusing on the case study of Mbigiri Estates. Soil pH is a critical soil parameter that significantly influences crop growth and productivity which also include other factors like soil texture, soil type, as well as drainage patterns. Traditional methods of soil pH assessment are time consuming and labor-intensive, making it challenging to obtain accurate and up-to-date information for large agricultural areas. Remote sensing techniques offer a promising approach to efficiently and effectively characterize soil pH over large areas. In this study, spectral analysis was employed to estimate soil pH levels in the sugarcane fields of Mbigiri Estates. These data were then correlated with spectral indices derived from satellite imagery, such as the Normalized Difference Vegetation Index (NDVI), the land surface temperature (LST) and soil moisture index (SMI)The relationships between these spectral indices and soil pH were quantified using statistical analysis techniques. The results revealed significant correlations between the spectral indices and soil pH, demonstrating the potential of remote sensing for soil pH characterization. Furthermore, a soil pH map was generated for the study area using the developed theoretical views. This map provides spatially explicit information on soil pH variations within the sugarcane fields, enabling targeted soil management strategies for optimizing sugarcane production. The findings of this study contribute to the advancement of precision agriculture techniques by leveraging remote sensing technology for efficient and site-specific soil pH management in sugarcane farming systems.

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LIST OF ABBREVIATIONS

USGS	United states geological survey earth explore
UNFCCC	United Nations Framework Convention on Climate Change
pH	Potential of hydrogen
MLR	Multi linear regression
LST	land surface temperature

CHAPTER ONE
INTRODUCTION

1.1 Background

Soil pH is the measure of acidity or basicity of the soil (A.D.Robson, 1989). Soil pH is the key characteristics that can be used to make characteristics that can be used to make informative analysis both qualitative and quantitative regarding soil characteristics, it's the master variable that affect the many chemical process. Soil and crop productivity are linked to soil pH though soil ph. generally range from 1 to 14, the optimal range for most agriculture crop is between 5.5 and 7.5. however, some crops adopted to thrive at soil pH values out of that optima range value (Odotola 2019). The united states department of agriculture and natural resources conservation service groups soil pH values as follows: ultra-acidic (5.1-5.5), extreme acidic (3.5-4.4), very strong acid (4.5-5.0), moderate acid(5.6-6.0), slightly acidic (6.1-6.5), neutral(6.6-7.3), slightly alkaline (7.4-7.7), moderate alkaline(7.9-8.4), strongly alkaline (8.5-9.0) and very strongly alkaline(>9.0) (Oshunsanya, Relevance of soil pH to agriculture, 2018). Soil physical properties like soil texture has direct effects on soil pH, water holding capacity, crop yield, production capabilities and nitrogen loss in a field (lund et., 2001).) generally soil pH is high during the dry season than in wet season (Wang et al.,2015; Fenget al.,2017). In dry areas soil salinity is a frequent consequence of irrigation and soil salinity has significance implication in soil health in fact the early detection of saline areas can be used to enact the preventive measures before crop is affected by damage (Ghazali,2019)

Agriculture in Tanzania is an important occupation for over 75 per cent of inhabitants (UNFCCC, Challenges and Opportunities for Mitigation and Adaptation in the Agricultural Sector, 2008). It is the mainstay of the majority of the households in the Southern Highlands where weather conditions are favorable for growing various food and cash crops. Sugarcane is among of the crops that is highly grown crop in Tanzania as it is both important food crop and commercial crop, the concentrated region for production include Morogoro, kagera and Kilimanjaro (TAKAMURA,1998). Currently most sugarcane is grown in estates, owned by sugar processing factories as well as contract growers (Tarimo& Takamura 1998) and this include Mkulanzi holding company limited which own Mbigiri estate in Morogoro kilosa. In order to increase and sustain future sugar production in Tanzania improvement in soil management of sugarcane fields, irrigation technology and use of the improved clones should be introduced. Climatic variability and climatic change result in change in rainfall pattern and extreme high and low temperature events, floods, drought and other abiotic stress. The result of climatic change in agriculture lead to food security as most of the production depend on rain with limited of no proper irrigation. Sugarcane is strongly influenced by the impacts of long-term climatic change as well as local weather and season variation it affects both growth and the development of plants and may harm crops. Soil nutrients management is the most emphasized aspect of the agro-technology in increase the crop production and sugarcane yields. Decline of soil fertility resulting to depletion of essential nutrients became the reason for low production (Bell et al.2001: Garside et al.2023). soil is one of the main factors which increase production according to its chemical composition particularly nitrogen and potassium which plays a major role in physiology, growth and development (Malavolta 1994: Rice et al.2002).

Sugarcane is a management responsive crop: therefore, soil-plant relationship is to be monitored during all the phases the plant. The condition of plant, as well as the soil, takes so many turns in entire period as the crop remains in the field for more than one year facing all the extremes of rainfall, temperature, sunlight, humidity etc. Therefore, it is recommended to maintain the congenial soil climate for good growth of plant by its proper management in various extreme conditions i.e. irrigations in dry period, maintaining drainage of excess water. (Ashok K, 2012)

According to production guidelines (2014) of the department of agriculture, forestry and fisheries sugarcane soil requirements it include all the classes of soil pH but it grow well in deep, well-drained soil of medium fertility of sandy loam soil texture with soil pH range from 6.0-7.7. the optimal pH is about 6.5 but sugarcane can tolerate considerable degree of soil acidity and alkalinity. Waterlogged soil, which have no drain are not suitable because sugarcane is salt sensitive plant.

Low soil fertility is currently the major factor contributing to low sugarcane production and productivity in Tanzania. Many sugarcane farmers have been growing the crop without fertilizer application or inappropriate use of fertilizers as most of them do not test their soils. Thus, declining soil fertility is a common trend in sugarcane farms. The low soil fertility causes frequent outbreak of nutritional diseases such as necrosis due to nitrogen deficiency, discolouration due to phosphorus deficiency, chlorosis due to potassium deficiency, mottling and chlorosis due to calcium and magnesium deficiencies etc, all of which resulting to poor tillering, slender stalks, stunted growth and reduced yield.

Any sound agricultural investment requires good management of soil resources for high and sustainable production. Thus, a regular soil health testing is essential to maintain not only yield targets but also quality of the produce. Therefore, the main objective for undertaking soil fertility evaluation in Mbigili and Mkulazi is to help the management to make rational use of land resources for improved sugarcane production while maintaining resilient ecosystem. To satisfy this need, soil fertility is assessed not only for the nature and degree of constraints but also for the feasibility of improvement measures required to mitigate the identified constraints. (Mwango,2020)

As soil pH being one of the factor to be considered in application of fertilizers, irrigation plans as well as the time for crop planting and harvest, where both of this may lead to proper yield there is need to map and study the soil pH characterization at Mbigiri estate as it's the one among the sugarcane plantations which face the problem of soil pH in relation to proper use of fertilizers which lead to low production (Mwango G 2020).

This study intends to use remote sensing data to identify and map the areas which are acidic and alkaline so that growers will use in application of fertilizers to increase sugarcane production. (Ghazali,2019)

1.2 Research Problem

Sugarcane is an important commercial crop in Tanzania it's the main source of sugar produced for both export and domestic consumption, currently production of sugar does not satisfy the domestic market due to low production, most sugarcanes are grown in estates owned by sugar processing factories, soil pH is one among the factors that affect the growth the crops in the estates, Soil pH is an important variable s it's a quality indicator or as it controls different biological and chemical processes happening in the soil. pH measures the acidity or alkalinity which manage cropping process since it controls the nutrients availability for the crop and soil, changes in soil pH affect the availability of many nutrients and activity of the soil. Adding composite/fertilizers as soil amendments can rise and reduce soil pH so in one way or another both actions affect the crops yield and production. There have been low production of sugarcane/inefficiency production of sugarcane due to unknown soil PH which make difficulty in fertilizers application for enough yields. By using the application of remote sensing data soil pH can be determined easily in a certain area and hence proper fertilizers application.

1.3 Objectives

1.3.1 Main Objective

Optimizing sugarcane production in Tanzania through remote sensing-based soil pH characterization.

1.3.2 Specific Objectives

i. Identifying the influence of soil pH on sugarcane growth and yield.
ii. To show the relationship between land surface temperature and soil ph.
iii. To assess the relationship between soil pH and soil moisture.

1.4 Research Questions

i. What is influence of soil pH on sugarcane growth and yield?
ii. What is the relationship between land surface temperature and soil ph. ?
iii. What is the relationship between soil pH and soil moisture?

1.5 Significance of the Research

Upon completion of this research will contribute much for identify areas where soil pH may be limiting sugarcane, to identify the spatial variability of soil pH in sugarcane growth and production, this information can help farmers and other stakeholders make informed decisions about how to improve soil pH and increase sugarcane yields and the type of fertilizers to be used but also develop sustainable practices that can improve sugarcane production. But also Providing new and valuable information about the variation of soil pH in sugarcane plots for fertilizers applications.

1.6 Beneficiaries

i. Government especially the ministry of agriculture,

The results sugarcane yield will help the government in crop insurance purposes, delivery estimates, planning for storage requirement and cash flow budgeting (import and export). This is due to the fact that the result will show the way soil pH is distributed in the farms.

ii. Mkulanzi holding company limited,

The knowledge and the maps from this research will help them in increase production by proper application of fertilizers according to the soil pH category it will also help to reduce the uncertainty of sugarcane production.

iii. Decision makers,

This will make the decide on the areas to grow sugarcane, season for growth and the type of fertilizer to use so as to boost the soil fertility favorable for sugarcane growth.

1.7 Scope and limitation of the research.

The study will focus on the factors which related to soil pH in order to determine the estimated soil pH from the remote sensing data. From remote sensing data like Landsat 8 at Thermal infrared band (band 6 or band 10) this band can be used to estimate the temperature of the soil surface, which can be related to the soil moisture and soil temperature. which have different specific bands which are essential in determine the indices that has the strongest association with availability of soil pH in a certain farm. However, the study cannot inclusively generate soil pH direct from the soil thus there is no direct remote sensing data which provide soil pH but also soil pH is the result of a lot of associated factor like soil texture, type of the soil but also the location of the farm, but this study will only consider soil moisture as one of the factors which have direct relationship with soil Ph.

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview

This chapter will elaborate how other people talked about soil Ph from GIS and RS perspective, also this chapter will give the insight on how remote sensing with the help of satellite data can be used to characterize soil pH for better results as it also includes the kind of precise agriculture. This is by showing how soil pH and soil moisture from satellite image can be related so as to predict the soil pH for the application of fertilizer to optimize production of sugarcane in Mbigiri estate.

About sugarcane in Mbigiri estates

Sugarcane production is an essential agricultural activity in many countries, providing a significant source of income and employment but also its one of the source of other products hence it acts like a raw material in both food stuffs and other materials (Singh, 2017). Mbigiri estate is one of the largest sugarcane producers in the region, and optimizing production is crucial for the estate's economic growth. One of the factors that affect sugarcane production is soil pH, which plays a vital role in plant growth and nutrient uptake (Thibane, 2023). Remote sensing technology has been used to characterize soil pH and optimize sugarcane production as the study and output will be used for better applications of fertilizers with time given and this is to say the wet season and dry seasons as its kind of fertilizers because soil pH is a sensitive case as its change just with the change of the single factor (Thibane, 2023). This literature review provides an overview of remote sensing-based soil pH characterization and its application in optimizing sugarcane production in Mbigiri estate.

The information of soil moisture and soil salinity play an important role in supporting the agriculture sustainability. Soil moisture and soil salinity are defined as the water and salt contents in soil. Understanding the soil moisture and salt concentration are important as sugarcane is the mostly used crop nationally and international meaning for both import and export (Luster, 2009). A sufficient amount of rainfall is required to make the sugarcane fields receive enough water supply during the rainy season (Scheberl, 2019). During rainy season, salt content tends to be decreased while during the dry season it tends to increase. Most of the researchers discuss the importance of monitoring and assessing the soil moisture in agricultural land. But for the case of Mbigiri estates they mostly no a dependent of rainfall season for their production. They state that soil moisture is very important to control the plant growth and changes in soil pH during the planting period and crop. (Budi et al, 2020)

2.2 Soil pH information in Mbigiri estates

The optimum soil pH for sugarcane is about 6.5-7 (Barnes, 1974; Sugarcane Production Handbook, 2001) but sugarcane can grow in soils with pH in the range of 5 to 8.5 (NETAFIM, 2017). Most of the macronutrients such as N, P, K, Ca and Mg are best utilized by the plants when the soil pH ranges between 5.5 and 7.9. The uptake of most of the micronutrients takes place in acidic medium. However, under acidic conditions (pH less than 5.2), the adverse effects are due to aluminum, iron and manganese toxicity. Alkaline soils with pH ranging between 7.4 and 8 are generally deficient in Zn, Fe and P (Marschner, 1986). Sugarcane is moderately sensitive to soil salinity and the decrease in crop yield varies with the level of soil salinity. Liming is required if pH is less than 5.0, or gypsum application if pH is more than 9.5.

Most soils of Mbigiri farm ranges from 6.6 to 7.3 which is neutral, except few areas particularly Blocks B5, B51, C8, C12, C13, D12 and D13 which have higher pH ranges from 7.4 to 7.8 which are slightly alkaline, and a pH of 6.5 for Block F3 which is slightly acidic. The pH ranges are favorable for sugarcane crop. Whereas in Mkulazi the soil pH ranges from slightly acidic to neutral in most Blocks with some few Blocks having alkaline pH values. (Sibaway & Mgohele, 2020)

2.3 Remote Sensing-Based Soil pH Characterization

Remote sensing technology is an efficient and cost-effective method of collecting information on soil characteristics, including pH. The technology involves using sensors mounted on platforms such as satellites, aircraft, or drones to capture data on soil reflectance. The reflectance data is then analyzed to determine soil pH levels, among other soil characteristics. Several remote sensing techniques have been used to characterize soil pH, including hyperspectral, multispectral, and thermal imaging (Wulf, 2014).

Hyperspectral remote sensing involves capturing reflectance data at multiple narrow spectral bands, providing detailed information on soil characteristics. Various studies have shown the potential of hyperspectral remote sensing in characterizing soil pH. For instance, Wang et al. (2020) used hyperspectral remote sensing to determine soil pH in a sugarcane plantation in China. The study showed a high correlation between soil pH and hyperspectral data, indicating the potential of the technique in optimizing sugarcane production.

Multispectral remote sensing involves capturing reflectance data at a few broad spectral bands, providing less detailed information than hyperspectral remote sensing. However, multispectral remote sensing is more efficient and cost-effective than hyperspectral remote sensing. Several studies have shown the potential of multispectral remote sensing in characterizing soil pH. For instance, Huang et al. (2018) used multispectral remote sensing to determine soil pH in a sugarcane plantation in Brazil. The study showed a high correlation between soil pH and multispectral data, indicating the potential of the technique in optimizing sugarcane production.

Thermal imaging involves capturing infrared radiation emitted by the soil surface, which is influenced by soil temperature and moisture. Several studies have shown the potential of thermal imaging in characterizing soil pH. For instance, (Nagler et al, (2013) used thermal imaging to determine soil pH in a sugarcane plantation in Arizona. The study showed a high correlation between soil pH and thermal data, indicating the potential of the technique in optimizing sugarcane production.

2.4 Optimizing Sugarcane Production in Mbigiri Estate

Several studies have shown the potential of remote sensing-based soil pH characterization in optimizing sugarcane production. For instance, Jha et al. (2021) used hyperspectral remote sensing to determine soil pH in a sugarcane plantation in India. The study showed a significant correlation between soil pH and sugarcane yield, indicating the potential of the technique in optimizing sugarcane production. Similarly, Zhang et al. (2020) used multispectral remote sensing to determine soil pH in a sugarcane plantation in Australia. The study showed a significant correlation between soil pH and sugarcane yield, indicating the potential of the technique in optimizing sugarcane production.

Remote sensing-based soil pH characterization can also help in identifying areas of the sugarcane plantation with suboptimal soil pH levels. This information can be used to implement targeted soil management strategies such as liming and fertilization, which can help to optimize sugarcane production. For instance, Chen et al. (2019) used hyperspectral remote sensing to identify areas with suboptimal soil pH levels in a sugarcane plantation in China.

2.5 Soil pH and other related factors

Soil pH is a measure of soil acidity or alkalinity. It is an important indicator of soil health. It affects crop yields, crop suitability, plant nutrient availability, and soil micro-organism activity, influencing key soil processes. Soil pH can be managed by practices such as applying the proper amount of nitrogen fertilizer, liming, and using cropping systems that increase soil organic matter content and improve overall soil health. (tammy, 2014)

Inherent factors that affect soil pH include climate, mineral content, and soil texture. Natural soil pH reflects the combined effects of the soil-forming factors (parent material, time, relief or topography, climate, and organisms). The pH of newly formed soils is determined by the minerals in the parent material. Temperature and rainfall affect the intensity of leaching and the weathering of soil minerals. In warm, humid environments, soil pH decreases over time through acidification due to leaching from high amounts of rainfall. In dry environments where weathering and leaching are less intense, soil pH may be neutral or alkaline. Soils that have a high content of clay and organic matter are more resistant to changes in pH (higher buffering capacity) than are sandy soils. (tammy, 2014) Although clay content cannot be altered, organic matter content can be altered by management practices. Sandy soils commonly have a low content of organic matter, resulting in a low buffering capacity and a high rate of water percolation and infiltration. Thus, they are susceptible to acidification.

2.6 Regression analysis

Is the statistical method used to analyze the relationship between the dependent and the independent variable, where the dependent variable is what we intend to produce while independent variable is used as the input. R in a regression analysis is called the correlation coefficient and it is defined as the correlation or relationship between an independent and a dependent variable, regression analysis approaches help establish causal relationships between variables, modelling time series, and forecasting. Regression analysis, for example, is the best way to examine the relationship between sales and advertising expenditures for a corporation. (Sharma, 2022)

2.6.1 The purpose of regression analysis

Regression analysis is used for one of two purposes: predicting the value of the dependent variable when information about the independent variables is known or predicting the effect of an independent variable on the dependent variable. Which is also a part of the study to analyze the relationship between the soil moisture and the soil pH so as to make prediction on the soil pH around the Mbigiri estates for fertilizers application impact. (Sharma,2022)

There are number of types of regression analysis and this include the following

2.6.2 Linear Regression

The most extensively used modelling technique is linear regression, which assumes a linear connection between a dependent variable (Y) and an independent variable (X). It employs a regression line, also known as a best-fit line. The linear connection is defined as Y = c+m*X + e, where 'c' denotes the intercept, 'm' denotes the slope of the line, and 'e' is the error term. (Sharma, January 19, 2022)

The linear regression model can be simple (with only one dependent and one independent variable) or complex (with numerous dependent and independent variables) (with one dependent variable and more than one independent variable).

2.6.3 Multiple regression

Multiple linear regression extends simple linear regression to include more than one explanatory variable. In both cases, we still use the term 'linear' because we assume that the response variable is directly related to a linear combination of the explanatory variables. (Tranmer, Jan 2020)

The equation for multiple linear regression has the same form as that for simple linear regression but has more terms:

$yi = \beta0 + \beta1x1i + \beta2x2i + \cdots + \beta pxpi + ei$……………………………………..……Equation 2.1

As for the simple case, β0 is the constant – which will be the predicted value of y when all explanatory variables are 0. In a model with p explanatory variables, each explanatory variable has its own β_coefficient.

Again, the analysis does not allow us to make causal inferences, but it does allow us to investigate how a set of explanatory variables is associated with a response variable of interest. (Tranmer, Jan 2020)

2.6.4 Non-linear regression

Nonlinear regression is a statistical technique used to model the relationship between a dependent variable and one or more independent variables when the relationship is not linear. In nonlinear regression, the relationship between the variables is described by a nonlinear equation, which can take various forms such as exponential, logarithmic, polynomial, or trigonometric functions.

The general form of a nonlinear regression model is;

$y = f(x, \beta) + \varepsilon$ ……………………………………………………………………..…Equation 2.2

where y is the dependent variable, x is the independent variable, β represents the parameters of the model, f is the nonlinear function that describes the relationship between the variables, ε is the random error term.

The goal of nonlinear regression is to estimate the values of the model parameters (β) that best fit the observed data. This is typically done by minimizing the sum of the squared differences between the observed values and the predicted values from the nonlinear model. Various optimization techniques, such as the Gauss-Newton method or the Levenberg-Marquardt algorithm, are commonly used to find the optimal parameter values.

Nonlinear regression is often used in fields such as economics, biology, physics, engineering, and social sciences, where the relationships between variables are expected to follow nonlinear patterns. It allows for more flexible modeling and can capture complex relationships that cannot be adequately represented by linear regression model.

CHAPTER THREE
METHODOLOGY

3.1 Overview

This chapter includes description of methodology used in achieving the research objective which is the main objective and the specific objectives. This chapter explain the way through which we can estimate the soil pH values of the rest of Mbigiri farm using satellite images specifically its Landsat images where the several bands where used to calculate different parameters which can lead to the soil moisture index this include the NDVI, LST, BT, TOA, Pv and emissivity.

3.2 Description of the study area

The study area is Mbigiri estate Morogoro, Kilosa district Mbigiri esates covers the total area of 4,856 hectors for cultivation activities and infrastructure which equals to 48.56sqk, which is under Mkulazi holding company limited. Kilosa district spans from 36 to 38 degree east and from 6 to 8-degree south of equator. It has the total area of 12,394 square kilometers of which 536,580 hectares is arable for land is used for agriculture. According to the Population and Housing Census of 2012, Kilosa District had a population of 438,175. The Kilosa District Council has an average annual rainfall of between 800 mm to 1600 mm depending upon the altitude. The temperature in the District varies with altitude as well. The average annual temperature is 25°C with the coldest month being July and the hottest month being March. The average annual temperature ranges from 19°C to 30°C. The Kilosa District Council has 58 rivers that help with providing water for domestic uses, livestock, irrigation and fishing grounds. These rivers are a significant value to the District and directly contribute to the quality of life of the residents

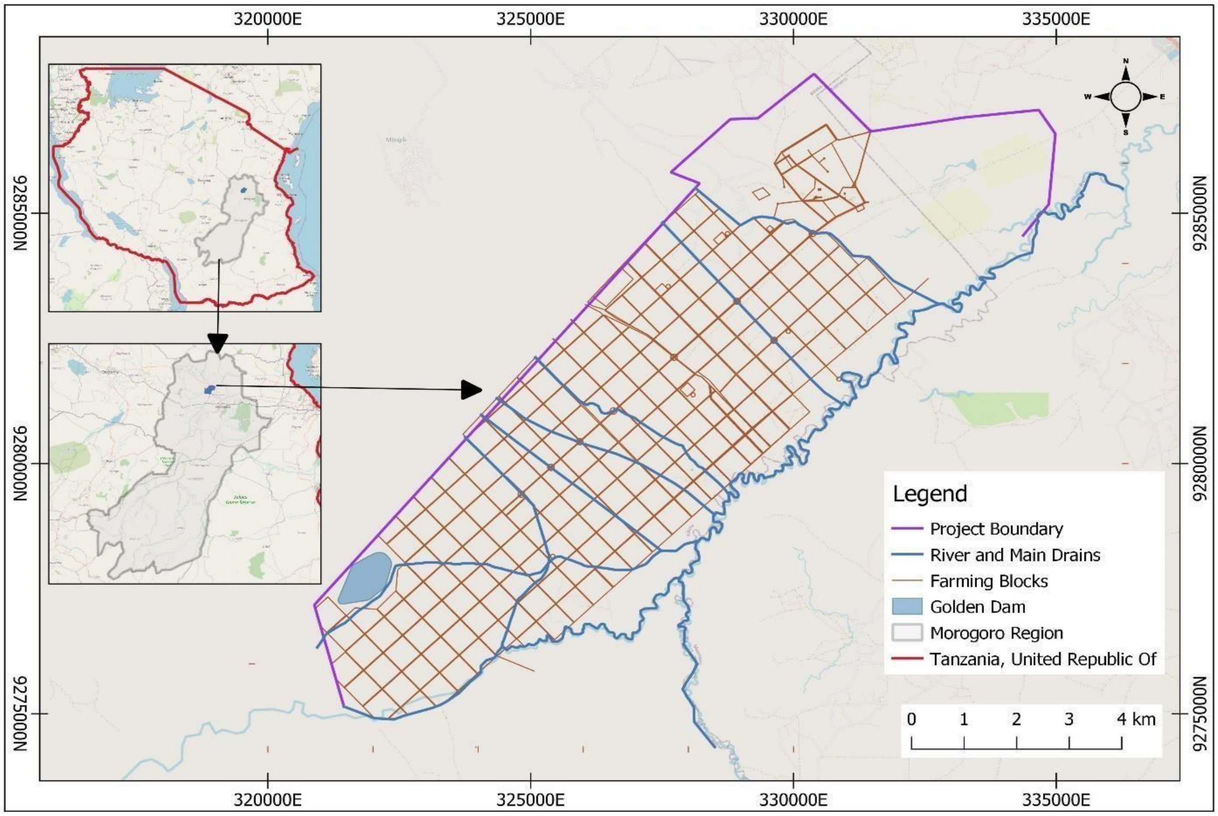

Figure 3.1: location map

This study will estimate the soil pH available in Mbigiri estates from the relationship between the soil moisture obtained from the satellite image which is Landsat 8 band 10 which thermal infrared band which is used to generate TOA band 4&5 used for NDVI generation and the soil samples from the field where other samples will be used for validation.

The Landsat-8 data with two sensors (Operational Land Imager OLI/Thermal Infrared Sensor TIRS) were used and downloaded from USGS website https://earthexplorer.usgs.gov/. Downloading was carried out by defining the location of the study area using path/Row and the data were acquired in the three target periods. Table (2) describes the specifications of Landsat-8 (OLI/TIRS) data.

Table 3.1 characteristics of landsat

Table 3.1 shows the characteristics of landsat 8 which include the spatial, temporal production level

Spatial resolution	30m
Temporal resolution	16 days
Production level	Collection 1&2 level 1

3.3 Soil Moisture Index estimation (SMI)

The soil moisture index (SMI) is the ratio of the difference between present soil moisture and the permanent wilting point to field capacity and residual soil moisture. This indicator ranges from 0 to 1, with 0 representing dry conditions and 1 representing moist conditions. Determination of SMI requires the computation of the maximum and minimum values of LST as explained in equation follows.

$$SMI = \frac{LSTmax - LST}{LSTmax - LSTmin} \quad \text{...Equation 3.1}$$

Where: SMI is Soil Moisture Index, LST_{max}, LST_{min}, and LST: are the maximum, minimum, and value of the retrieved LST respectively.

Table 3.2 data type and their sources

The following figure shows the types of data used and the way the data have been used as well as the sources of the data.

S/N	DATASETS	RESOLUTION	FORMAT	USES	SOURCES
1	Landsat 8	30m	Tiff	To generate soil moisture and NDVI	United states geological survey(USGS) earth explore.(https:earthexplore.usgs.gov)
2	Field data	-	-	Map the distribution of soil pH the estates	Mkulanzi holding company limited.
3	Administrative boundary		shp	Show the area of Mbigiri estates	Mkulanzi holding company limited.

h

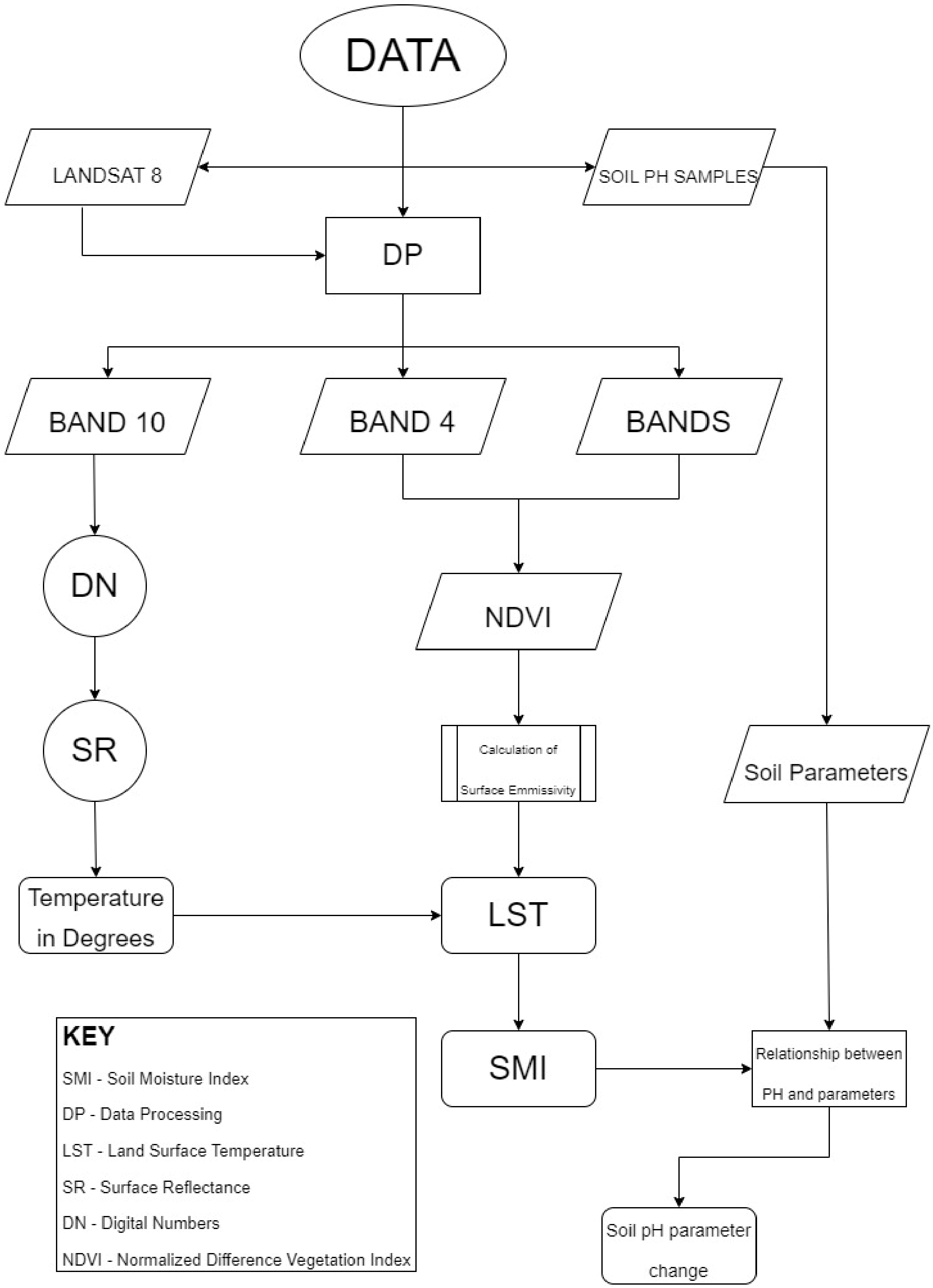

Figure 3. 2: Flow chart

3.4 Data Preparation and Processing.

order to use the remote sensing data, pre-processing was required so as to prepare the data for further analysis. The preprocessing steps involved in both the soil pH and satellite data was preprocessed, where the soil pH data was written in the excel form to ensure that there is values for correlation purpose as well as the soil moisture is the quantified to ensure the correlation with the other data given. Then Correlation analysis between soil pH data and soil pH and temperature data was performed so as to understand the relationship between the dataset either they have a strong relationship or a weak relationship. The data were then combined and arranged on excel as csv file format ready for processing

3.5 Soil Moisture

Soil moisture can be generated following the following steps and explanations and the methodology. Converting Digital Numbers (DN) to Top of Atmosphere (TOA) Reflectance

The values in the downloaded raw Landsat 8 satellite images were geometrically corrected and for our analysis and calculation of the LST only Band 10 and Band 11 were needed. First the digital numbers from the Landsat images have to be converted to at-sensor spectral radiance which is Top of Atmosphere TOA reflectance values using the following equation:

$\boldsymbol{L\lambda = ML * Qcal + AL}$ …………………………………………………………………. Equation 3.2

Where:

$L\lambda$ = TOA spectral radiance

band 10/ 11 image.

ML = Radiance multiplicative Band (10)

AL = Radiance Add Band (10)

To solve this equation RADIANCE_MULTI_BAND_X and RADIANCE_ADD_BAND_X were needed. These were obtained from the metafile of every Landsat 8 downloaded. These values (can) differ from image to image, so we had to make sure are revised for every scene!

Satellite Brightness Temperature

After converting DN values to at- sensor spectral radiance, the reflectance values from the TIRS band data were converted to brightness temperature (BT) which in this case the LST is in Kelvin, hence this was done with the following equation and also needed some data from the metafile:

$$BT = \frac{K2}{\ln\left(\frac{k1}{L\lambda}+1\right)} - 272.15$$ ……………………………………………………………...Equation 3.3

Where:

BT = Top of atmosphere brightness temperature (°C)

Lλ = TOA spectral radiance (Watts/ (m2 * sr * µm))

K1 = K1 Constant Band (10)

K2 = K2 Constant Band (10)

Where K1 and K2 are the thermal constants of TIR band 10 which can be identified in the metadata file associated with the satellite image. To have the results in Celsius, it was necessary to revise by adding absolute zero which is approximately equal to -273.15.

Normalized Difference Vegetation Index (NDVI)

NDVI was essential to identify different land cover types of the study area. NDVI ranges between -1.0 to +1.0. NDVI was calculated on per-pixel basis as the normalized difference between the red band (0.64 - 0.67 µm) and near infrared band (0.85-0.88 µm) of the images using the formula.

The Normalized Differential Vegetation Index (NDVI) is a standardized vegetation index which Calculated using Near Infra-red (Band 5) and Red (Band 4) bands. Calculation of NDVI was necessary for further calculate proportional vegetation (PV) and emissivity (ε)

$$NDVI = (NIR - RED)/(NIR + RED))$$ ……………………….……………………………………….……….…Equation 3.4

Where:

RED= DN values from the RED band NIR= DN values from Near-Infrared band proportional vegetation (Pv) from NDVI This proportional vegetation gave us the estimation of area under each land cover type. The vegetation and bare soil proportions were acquired from the NDVI of pure pixels. Values of NDVIv = 0.5 and NDVIs = 0.2 were proposed to apply in global conditions While the value for vegetated surfaces (NDVIv = 0.5) may be too low in some cases, for higher resolution data over agricultural sites, NDVIv can reach 0.8 or 0.9. Pv can be calculated using the equation below

$\boldsymbol{PV} = [(\boldsymbol{NDVI} - \boldsymbol{NDVImin})/(\boldsymbol{NDVImax} + \boldsymbol{NDVImin})]\hat{}\mathbf{2}]^{\mathbf{2}}$……...……………………………………………………..…...Equation 3.5

Where:

PV = Proportion of Vegetation

NDVI = DN values from NDVI Image

NDVI min = Minimum DN values from NDVI Image

NDVI max = Maximum DN values from NDVI Image

Land surface emissivity

This was required to estimate LST since, LSE is a proportionality factor that scales the black body radiance (Plank's law) to measure emitted radiance and it is the ability of transmitting thermal energy across the surface into t+-he atmosphere. At the pixel scale, natural surfaces are heterogeneous in terms of variation in LSE. In addition, the LSE is largely dependent on the surface roughness, nature of vegetation covers etc.

$E = \varepsilon s * PV + \varepsilon v$ ……………………………………………………………………. Equation 3.6

Where,

E = Land Surface Emissivity, PV = Proportion of Vegetation, εv= vegetation emissivity, εs= soil emissivity Calculating LST

Calculating LST using brightness temperature (BT) of band 10 and LSE, the Land Surface Temperature (LST) was calculated using radiative temperature which was also calculated using Top of atmosphere brightness Temperature, Wavelength of emitted radiance, Land Surface Emissivity.

$LST = BT + W * (\frac{BT}{14380}) * \ln(E)$…………………………………...…………………Equation 3.7

Where:

BT = Top of atmosphere brightness temperature (°C),

W = Wavelength of emitted radiance,

E = Land Surface Emissivity

After calculating and estimating Land surface temperature the raster image that contain land surface temperature variables is added to R studio ready for creating land surface map.

Soil Moisture Index (SMI)

The soil moisture index (SMI) is the ratio of the difference between present soil moisture and the permanent wilting point to field capacity and residual soil moisture. This indicator ranges from 0 to 1, with 0 representing dry conditions and 1 representing moist conditions. Determination of SMI requires the computation of the maximum and minimum values of LST as explained in equation 3.8.

$SMI=(LST_{max} -LST)/(LST_{max} - LST_{min})$……………………….………………………..Equation 3.8

Where: SMI is Soil Moisture Index, LST_{max}, LST_{min}, and LST: are the maximum, minimum, and value of the retrieved LST respectively.

Performing regression analysis

For the better estimation of soil pH values regression analysis to be done also as the part of the methodology and the study. The regression includes the dependent and independent variable which are the soil pH and soil moisture of Mbigiri estates.

CHAPTER FOUR
RESULST AND DISCUSION

4.1 Overview

This chapter tend to show various outputs that are needed to answer the objectives and fulfill the purpose of the study, it also includes the discussions on the output and results generated from the data given. Each results are explained in this chapter.

4.2 Results

NDVI and LST

Soil moisture can be estimated using a combination of NDVI and LST data, based on the observation of NDVI from three Landsat 8 images the NDVI changes over time showing the variation in three years according to the distribution value of the NDVI, it has a minimum value of 0 and the maximum value of 1 During the 2020 the change of NDVI values was followed by the change of the surface temperature, high NDVI values followed by low temperature. This occur as the canopy in sugarcane plant contributed in reflection of solar radiation than as following and this can also be due to the fact that there is no specific growing season of sugarcane in Mbigiri estates. In general, based on the maps of estimated soil moisture shows the water content in the soil has slowly increased in the other parts of the farm in other years. Year 2021 shows that the water content is probably as the maximum level while at the previous year the soil moisture is at minimum rate which is the favorable for the growth of sugarcane the plants need well drained soil for the better growth.

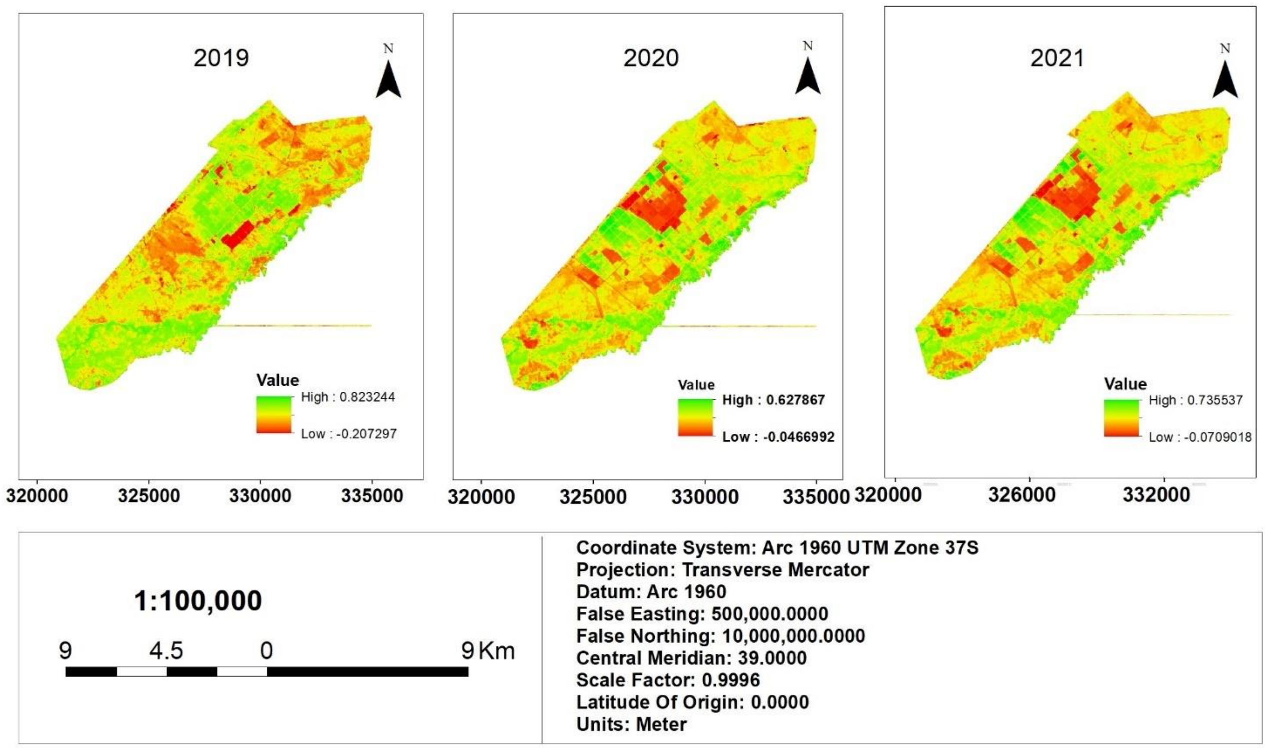

Figure 4.1 Variation of NDVI in Mbigiri Estate

Figure 4.2 show the variation of Landsat temperature from year which it also shows that the reflectivity also changes which also lead to change in soil moisture in Mbigiri estates though it's an indirect method used to determine soil pH in an area. Soil pH can indirectly influence LST through its impact on vegetation health and evapotranspiration. Acidic or alkaline soil conditions can affect plant growth and water uptake, which in turn can influence the cooling effect of vegetation and evapotranspiration rates. Well-vegetated areas tend to have lower LST compared to bare soil or areas with sparse vegetation. For this reason, sugarcane production is almost decreasing due to the rise of land surface temperature

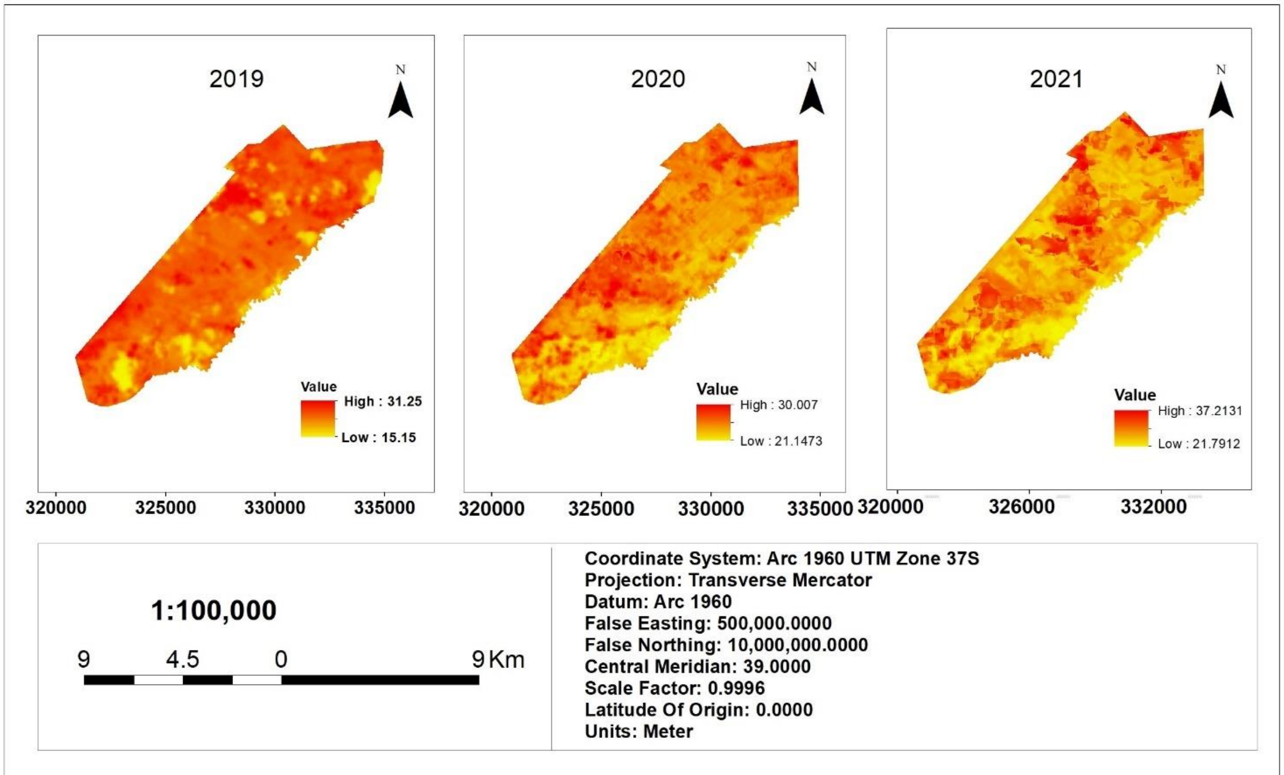

Figure 4.2: Mbigiri estates land surface temperature.

Figure 4.1, figure 4.2 and figure 4.3 of Mbigiri estate shows the amount of soil moisture for the three years which will later shows the implication of the relationship between the soil moisture and the soil Ph which will be used as the for estimation of the soil pH around the whole area for better fertilizers applications. From the following soil moisture maps it shows the difference in the soil moisture but also the soil moisture in Mbigiri estates tend to increase time to time and this is due to the fact that there is irrigation activities which are usually take place in that area as the reason of the ground to keep water for a long time, not only that Mbigiri estates uses the irrigation system throughout the year but also harvest and planting is also done through the year hence the area does not face the dryness in most of the parts

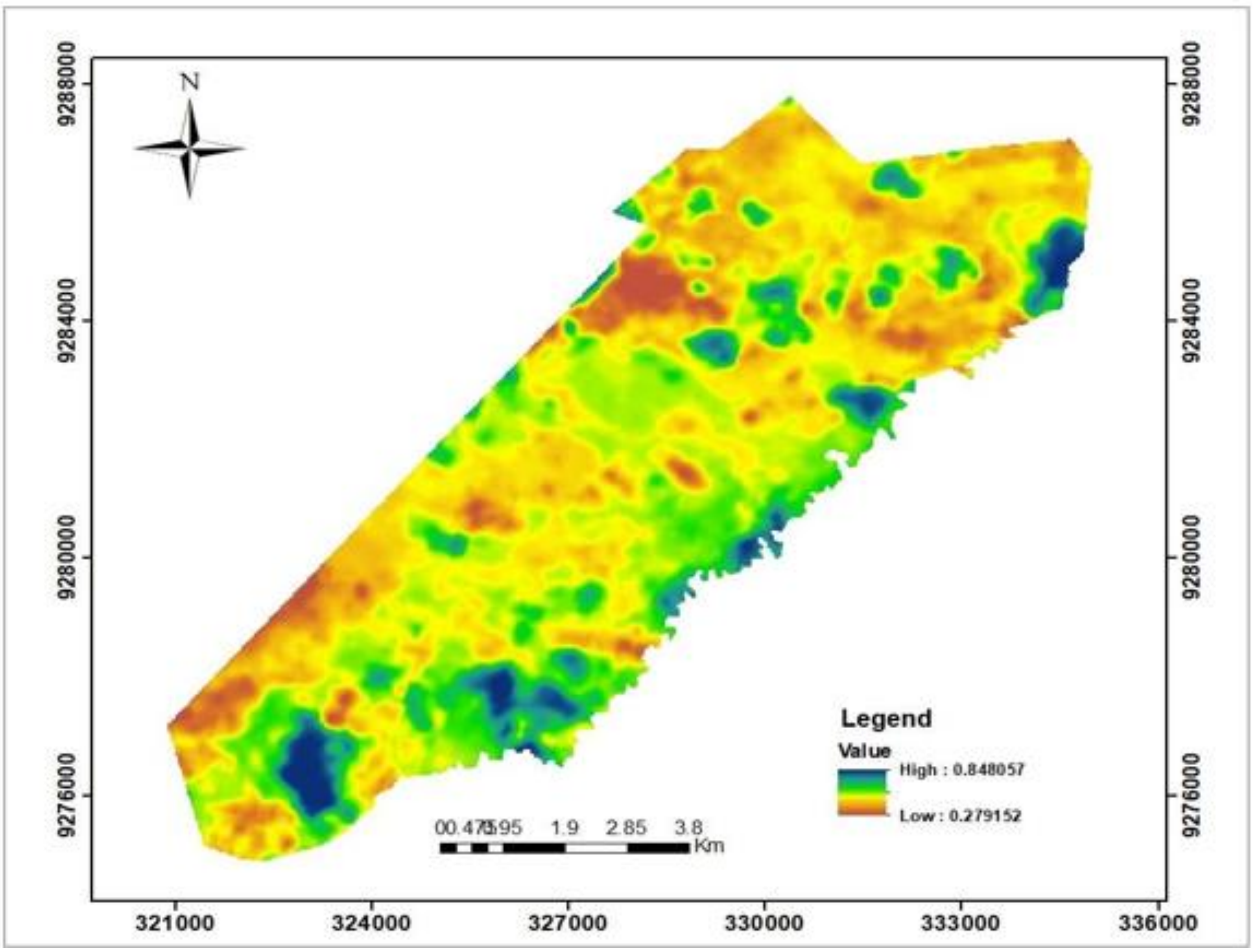

Figure 4.3: soil moisture index of Mbigiri estates in 2019

Figure 4.3 shows soil moisture analysis, the soil moisture tends to increase year after year as a good implication of the changes of soil moisture which may also lead to soil pH changes also as soil moisture play an important role in soil nutrients dissolver. This means that there is changes in soil moisture due to the irrigation activities that are taking place in Mbigiri estates.

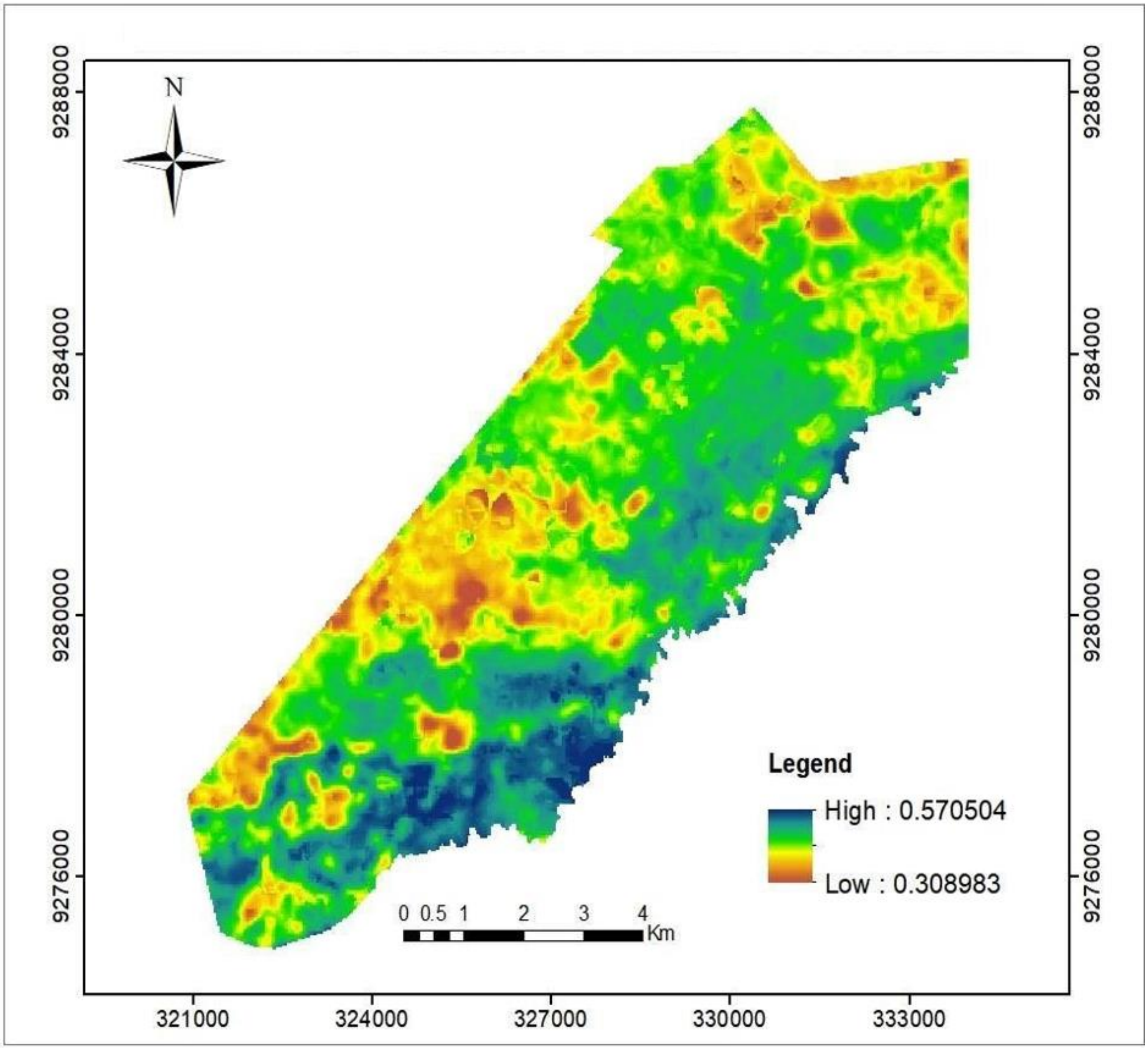

Figure 4.4: soil moisture index of Mbigiri estates in 2020

Figure 4.4 shows soil moisture analysis, the soil moisture tends to increase year after year as a good implication of the changes of soil moisture which may also lead to soil pH changes also as soil moisture play an important role in soil nutrients dissolver. For this figure 4.3 soil moisture tend to extend its boundaries differently from figure 4.1 and figure 4.2 This means that there is changes in soil moisture due to the irrigation activities that are taking place in Mbigiri estates.

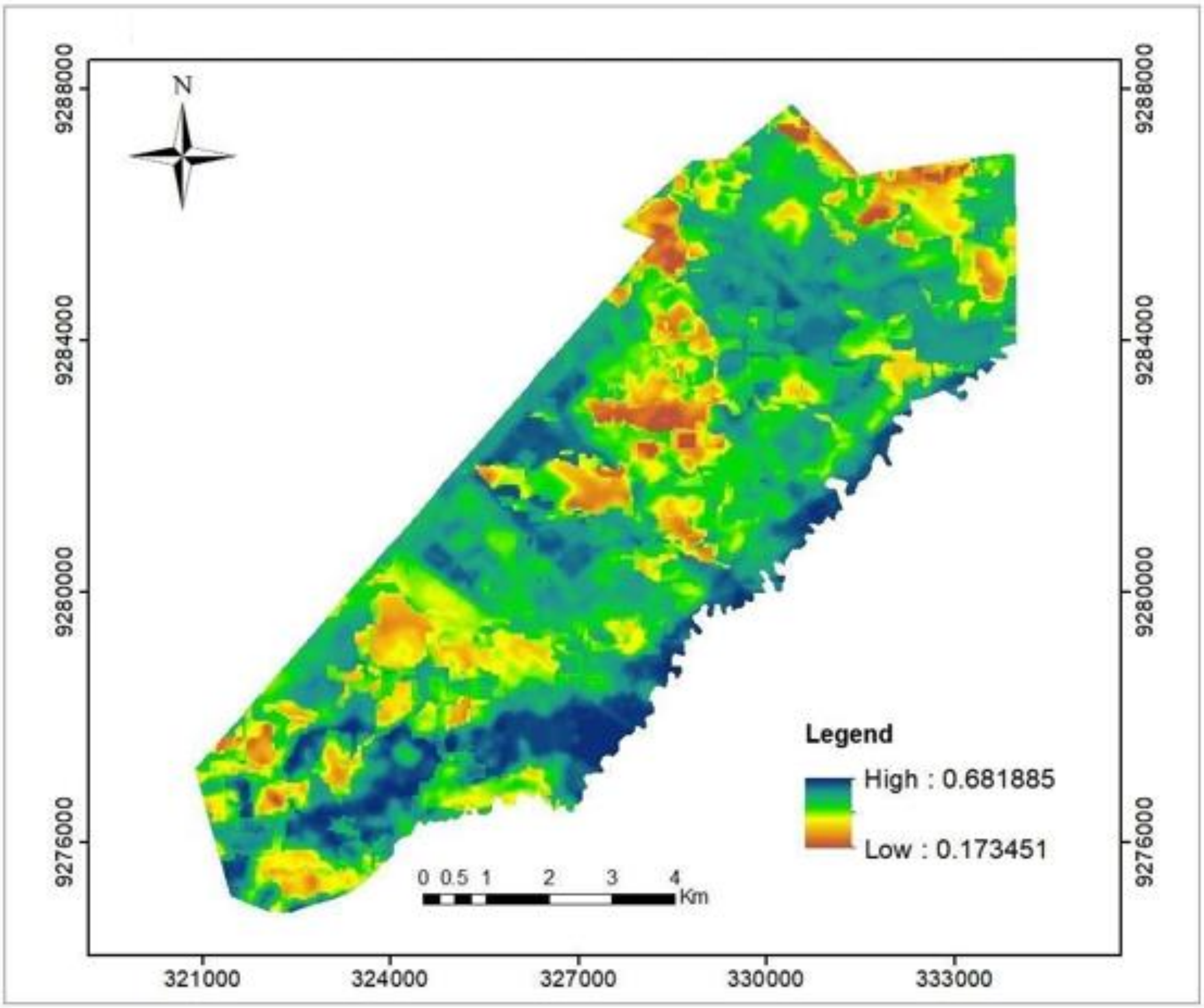

Figure 4. 4: soil moisture index of Mbigiri estates in 2021

Figure 4.5 map implies that the soil pH in the areas with range from 5.9-6.3 are the suitable soil pH for sugarcane production, considering the maps of the soil moisture index which indicate the increase in soil moisture in Mbigiri estates as the result of irrigation in the area which also does not cover the whole area and this can be due to the fact of other factors like elevation which implies that the water does not stay in the place irrigated but moves down the slope as the results some parts of the area lacking enough soil moisture for better absorption of the soil pH

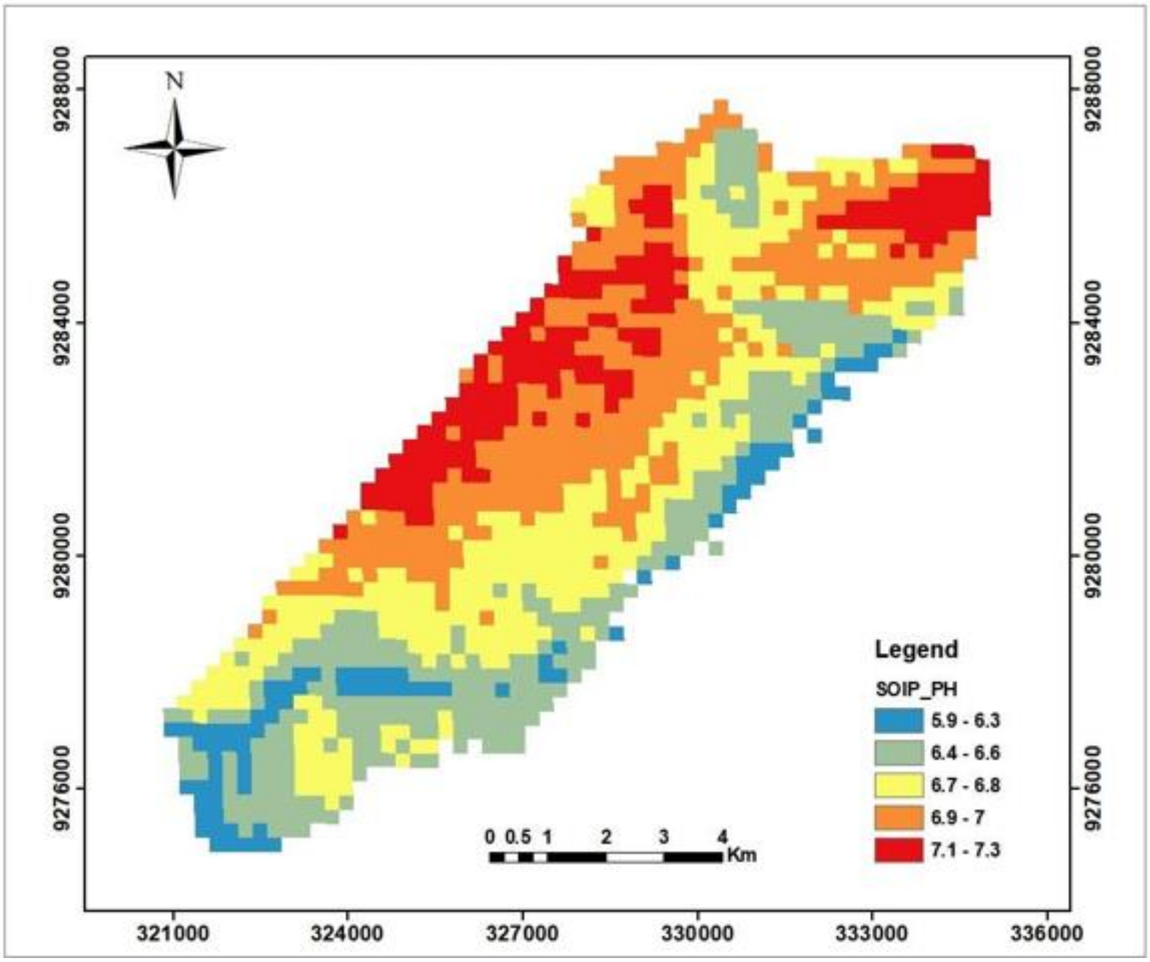

Figure 4.5: soil ph of Mbigiri estates.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The research was successful carried out. The analysis on soil moisture of Mbigiri estates analyzed in this research play the crucial role in ensuring the implications in soil Ph determination though it is an indirect method of determining soil pH in the farm because there other prevailing factors that may lead to soil moisture change soil moisture change also indicate the performance of soil pH because the places with favorable soil pH has enough soil moisture to retain and maintain the soil pH . Apart from that the analysis play crucial role in developing and improving adaptations strategies in sugarcane farming, which is the proper use of the fertilizers in Mbigiri based on the knowledge of soil Ph. The changes of the soil moisture in an area give us the picture that soil Ph can also change due to soil moisture change meaning that if there places which have high soil moisture it means that soil is also different in dissolving nutrients. The identified strategies include adaptation through irrigation and proper applications of fertilizers for better production. Based on the finings the research can only answer the variability in the soil pH as well as the NDVI performance on the sugarcane growth as the greenness indicated the favorable soil pH level.

5.2 Recommendations

Based on the findings and the results as well as the conclusion of this research, further studies in other factors which may lead to soil moisture change should be studied like soil type, climate, vegetation, and the management practices to accurately determine the nature of the relationship of soil pH and soil moisture in specific context, conducting controlled experiments of referring to scientific literature related to specific soil type and condition of interest is recommended. Considering other influencing factors affecting sugarcane production in Mbigiri which influence the decrease of sugarcane production each year. Apart from that am also recommending that the soil Ph samples should be collected in digital form assigning location so that it will be better for different Geographical Information Systems analysis.

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