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Influence of land use change on nitrate sources and pollutant enrichment in surface and groundwater of a growing urban areas

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INFLUENCE OF LAND USE CHANGE ON NITRATE SOURCES AND POLLUTANT ENRICHMENT IN SURFACE AND GROUNDWATER OF A GROWING URBAN AREAS

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A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Master's in Environmental Science and Engineering of the Nelson Mandela African Institution of Science and Technology

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ABSTRACT

In the present study, three-year (1997, 2008 and 2017) satellite images as well as different hydro-chemical parameters, nitrogen and oxygen isotopic composition of nitrate were used to examine the impacts of land use and land cover change on surface and groundwater quality. Through isotopic composition, sources of surface and groundwater nitrate contamination was also elucidated. The results showed significant land use transition whereby land use changed from forest and bare land to agricultural land and built-up areas. A slight reduction in the size of areas covered by water bodies was also observed, from 8 km^2 in 1997 to 7.4 km^2 in 2017. Results indicate differences in nitrate concentration that mirror land use changes. Samples with elevated levels of nitrate above 10 mg/L were located near agricultural fields and areas with intensive livestock keeping activities. In groundwater, δ^{15}N-nitrate and δ^{18}O-nitrate ranged from 3.2‰ to 20.1‰ with a mean value of 11.7 ± 1.8‰ and from 2.1‰ to 12.0‰ with mean value of 5.4 ± 1.8‰, respectively indicating nitrate was derived from inorganic fertilizer, manure and sewage. In surface water, δ^{15}N-nitrate and δ^{18}O-nitrate ranged from 2.4‰ to 19.3‰ with mean value of 4.9 ± 1.4‰ and from 1.5‰ to 21.9‰ with a mean value of 13.5 ± 2.8‰, respectively indicating nitrate from soil N. Isotopic composition data suggest sources of nitrate in groundwater dominated by synthetic and organic fertilizer application and to a lesser extent a natural soil nitrate source.

DECLARATION

I, Clarah L. Mallya**,** do hereby declare to the Senate of Nelson Mandela African Institution of Science and Technology that, this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

Clarah Leonard Mallya

_____ _____

Name and Signature of Candidate Date

The above declaration is confirmed by:

Mwemezi J. Rwiza

_____ _____

Name and signature of supervisor Date

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CERTIFICATION

The undersigned certifies that they have read and hereby recommend for acceptance by Nelson Mandela Institution of Science and Technology a dissertation titled, ***"Influence of land use change on nitrate sources and pollutant enrichment in surface and groundwater of a growing urban area in Tanzania"***, in partial fulfilment of the requirements for the degree of Master's in Environmental Science and Engineering of the Nelson Mandela African Institution of Science and Technology.

Mwemezi J. Rwiza

_____ _____

Name and signature of supervisor Date

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DEDICATION

To my lovely children, Derrick and Derricka as well as my husband, Domisian, for their prayers, care and support during my studies.

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LIST OF ABBREVIATIONS AND SYMBOLS

AfDB	African Development Bank
ASL	Above Sea Level
BAWASA	Babati Urban Water Supply and Sanitation Authority.
BH	Boreholes
ETM+	Enhanced Thematic Mapper Plus
GIS	Geographic Information system
GPS	Global Positioning System
LK	Lake
LULC	Land use Land cover
MEWES	Materials Energy Water and Environmental Sciences
MSS	Multispectral Scanner System
NM	Nelson Mandela African Institution of Science and Technology
OLI	Operational Land Imager
ROI	Region of Interest
SMOW	Standard Mean Ocean Water
SW	Shallow Wells
TM	Thematic Map
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

Nitrate (NO_3^-) contamination in surface and groundwater is a global environmental issue of concern (Choi *et al.,* 2007; Eppicha, 2012). High inputs of nitrate to surface and groundwater have been attributed to intensive land use, application of N-containing organic and inorganic fertilizers, animal manure, and discharge of human untreated sewage as well as natural sources like soils, bedrock and atmospheric deposition (Elisante & Muzuka, 2016a; Xue *et al.,* 2009). Groundwater is a major source of drinking water in Babati Township, where this study was conducted. Previous studies conducted in areas of Manyara region, where Babati town is located, have indicated that nitrate pollution above the background levels of 10 mg/L is common, which threatens the water quality of the area (Elisante & Muzuka, 2017; Hongoa, 2014; Pantaleo *et al.,* 2018a).

In many communities, land use and land cover (LULC) change is inevitable and it contributes towards pollution of water resources. The main anthropogenic drivers of LULC changes include deforestation, expansion of agriculture, conversion of wetland to pastureland and agriculture as well as urbanization (Miserendino *et al.,* 2011). For example, in Europe, it has been observed that modifications in landscapes have been largely caused by political and socio-economic changes which took place during the first half of the 19th century (Bičík *et al.*, 2015). Moreover, high and fast-growing population density in Africa has led to expansion of crop cultivation together with animal husbandry and consequent resettlement. These have been noticed as the major drivers of LULC changes (Tappan *et al.,* 2004).

Integration of natural and human factors in the classification of LULC dynamics can be a complex mixture; apart from anthropogenic activities on LULC changes, natural factors such as climate change and variability have also contributed (Reid *et al.,* 2000). A study conducted in the vicinity of Mount Meru, Tanzania, reported that many areas in Northern Tanzania have been converted to cultivated lands, grazing lands, human habitats, mining sites as well as industrial areas due to rapid increase in human population and consequent economic growth (Estes *et al.,* 2012; Kitalika *et al.,* 2018). Moreover, during the mid and late 1940s and in the late 1950s, many people migrated to Babati because of its fertile lands and easy access to the area's natural resources. Huge land in Babati was cleared due to tsetse fly infestation, while most of the virgin land was converted into farmlands (Sandström, 1995).

The LULC changes are considered to be associated with changes in the quality of surface and groundwater which threatens human and environmental health (Choi *et al.,* 2007; Namugize *et al.,* 2018). Moreover, in most developing countries, sources of nitrate in surface and groundwater have not been well studied. Babati is an emerging town, with rapid population growth resulting into high demand for housing, crop farming, grazing lands as well as sanitation facilities; consequently increasing the risk to water pollution (Hongoa, 2014; Sandström, 1995). Thus, it is imperative that sources and levels of aquatic pollutants be studied in such areas like Babati that will be the cities of tomorrow.

Intake of water with high nitrate concentration may cause several diseases including methemoglobinemia, gastric problems, thyroid gland retardation, even cancer (Tank & Chandel, 2010; WHO, 2011). Excessive loading of nitrate into lakes may cause eutrophication and hypoxia (Mitsch *et al.,* 2001). According to WHO, the acceptable limit of NO_3^- in drinking water is 50 mg/L. It is therefore, important to determine the levels, distribution and possible sources of nitrate in semi-urban aquatic environments in the developing countries of the world, especially in the rapidly growing urban areas.

The isotopic composition of N-nitrate (δ^{15}N-nitrate and δ^{18}O-nitrate) has been used to identify sources of nitrate because different sources of nitrate often have different isotopic signatures (Chang *et al.,* 2002; Kendall & Aravena, 2000; Mayer *et al.,* 2002; Pardo *et al.,* 2004). Synthetic fertilizers produced by fixation of atmospheric N_2 such as urea, ammonium nitrate and potassium nitrate usually show δ^{15}N values quite similar to that of atmospheric N_2 i.e. levels between –4‰ and +4‰ (Kendall & Aravena, 2000). Organic fertilizers such as plant composts and animal waste have a wider range of compositions of δ^{15}N from +2‰ to +30‰. Animal manure normally has high δ^{15}N values in the range of +10‰ to +20‰. Widory *et al.* (2005) reported δ^{15}N values for wastewater ranging from 10.3‰ to 23.5‰ and from 4.3‰ to 17.4‰. Nitrate derived from atmospheric deposition, has high positive δ^{18}O-nitrate values ranging from +50‰ to +94‰ (Durka *et al.,* 1994; Kendall *et al.,* 2007). Nitrate derived from nitrification, for instance, in soils or derived from mineralization of aquatic phytoplankton and nitrogen fixing bacteria followed by ammonification and nitrification has δ^{18}O-nitrate values between −15‰ and +15‰ that are dependent on the δ^{18}O of water (Deutsch *et al.,* 2006; Rock & Mayer, 2004). Also, nitrate derived from manure and sewage have δ^{18}O-nitrate values between −15‰ and +15‰ (Aravena *et al.,* 1993; Wassenaar, 1995). Since the values of δ^{15}N-nitrate from different sources may overlap, then a combined use of δ^{15}N and δ^{18}O values of nitrate can offer a delineation tool for discriminating the sources of nitrate in surface and groundwater (Kendall *et al.,* 2007).

In the present study, the contamination of surface and groundwater was examined by use of various approaches. This study aimed at examining the contribution of land use practices towards nitrate contamination in surface and groundwater. The study applied δ^{15}N-nitrate and δ^{18}O-nitrate dissolved in groundwater to determine the sources of nitrate in surface and groundwater of Babati town. Samples collected from existing wells, springs and Lake Babati ware used to produce the needed information. Levels of major cations, anions and trace elements were also analyzed, and the results were compared against the WHO drinking water guidelines.

1.2 Statement of the Problem

Babati is a growing town with rapid population increase leading to different land use practices. Babati Urban Water Supply and Sanitation Authority (BAWASA) has reported an increasing trend in the concentration of nitrate in various water sources in Babati town, however the sources and their relative contributions are not known. High concentration of nitrate in water contributes towards lack of access to clean and safe water. In order to identify sources of nitrate and whether LULC change contribute in increasing the levels of nitrate in surface and groundwater a comprehensive approach is needed to identify sources of nitrate and to assist in mitigation of nitrate intrusion in water for human consumption and ecosystem health.

1.3 Rationale of the Study

In the present study, we applied stable isotopic technique as environmental tracer to ascertain the contribution of land-use practices on the levels of nitrate in both surface and ground water systems in Babati. It was hypothesized that the identification of nitrate sources would trigger some action from the local water authorities to mitigate pollution in these water systems. Based on the evidence resulting from this study and the actions to be taken thereafter, water quality and suitability in the studied area may improve.

1.4 Research Objectives

1.4.1 General Objective

The main objective of this study is to identify the contribution of land use practices towards nitrate in surface (Lake Babati) and groundwater in Babati town, Tanzania.

1.4.2 Specific Objective

The present study addressed the following specific objectives:

(i) To assess the extent of land-use practices which have contributed to surface and groundwater pollution with nitrate.

(ii) To examine the sources of nitrate in surface and groundwater

1.5 Research Questions

This study was guided by the following research questions:

(i) To what extent have the land use practices contributed to nitrate levels in surface and groundwater?

(ii) What are other possible sources of nitrate in both surface and groundwater of Babati?

1.6 Significance of the Research

Land-use and land-cover change in Babati town seems to be fast. With rapid population growth and development in various economic sectors, water resources become vulnerable to contamination. This study will provide policy makers and other stakeholders with useful information for them to be able to balance the outcomes of land-use/cover change and the sustainability of water resources in this growing urban area. The findings of this study, thus, will help land-use planners to make suitable policies geared to minimizing the undesirable impacts of land-use cover changes in the sub-catchment.

1.7 Delineation of the Study

In the present study, three-year (1997, 2008 and 2017) satellite images as well as different hydro-chemical parameters, nitrogen and oxygen isotopic composition of nitrate were used to examine the impacts of land use and land cover change on surface and groundwater quality. The contamination of surface and groundwater was examined by use of various approaches. This study aimed at examining the contribution of land use practices towards nitrate contamination in surface and groundwater. The study applied δ^{15}N-nitrate and δ^{18}O-nitrate dissolved in groundwater to determine the sources of nitrate in surface and groundwater of Babati town. Samples collected from existing wells, springs and Lake Babati ware used to produce the needed information. Levels of major cations, anions and trace elements were also analyzed, and the results were compared against the WHO drinking water guidelines.

CHAPTER TWO

LITERATURE REVIEW

2.1 Land Use Practices and Water Quality Effects

Land use refers to human activities on land which are directly related to the land use description. It involves the management and modification of natural environment into built environment such as settlements, agricultural lands, pastures and managed woodland (Kiran, 2013). Understanding the LULC change and its trends of change is important for several reasons including land use planning and management. Therefore, land use data are required in the environmental analysis process and for the improvement of the current state (Kiran, 2013). Additionally, fine resolution satellite images provides opportunities for land cover monitoring as well as assessment (Chu *et al.*, 2013). The LULC changes are associated with both human activities and natural factors and affect the water quality (Baker, 2006). A transition from forestland into agricultural land or urban land may increase the rate of erosion, run-off and flooding. For instance in Guangdong Province in China, experienced a land use and cover change cover change from wasteland to urban land, wasteland to cropland, and cropland to orchards. On the other hand, wastewater facilities significantly contribute changes in the water quality (Wang, 2001).

A study conducted along Lake Victoria basin revealed that water pollution within the lake has recently increased whereby pollutants were derived from agricultural practices such as the use of pesticides, fertilizers, animal manure and unplanned settlements most of which sewage systems were directed to the lake (Machiwa, 2003). Therefore, this study will make the use of the Geographical Information System (GIS) remote sensing data in the classification of land use changes. Remote sensing techniques and GIS provide efficient methods for analysis of land use issues and are important tools for land use planning.

2.2 Health and Ecosystem Effects of Nitrate in Water

Elevated levels of nitrate in water is among the most serious environmental problems of our day (Mahvi *et al.*, 2005). In a lake system it stimulates the growth of aquatic plants and algae which will consume the dissolved oxygen during the decomposition of organic matter and hinder light penetration to deep water (Vitousek *et al.*, 1997). This will result into fish kills and other aquatic organisms leading to loss of biodiversity. When found in high concentrations and ingested via drinking water, nitrate may cause restriction of oxygen transport in blood circulation in infants as well as cancer in adults after long exposure (Ward *et al.*, 2018).

2.3 Application of Remote Sensing and Geographical Information System Data

Remote sensing and GIS data are progressively becoming significant tools in assessing the land-use and land cover changes. This is because most of the data required for land-use land cover change detection can easily be obtained from remotely sensed images. Remote sensing has the capacity to acquire signatures at once over large land areas. The spectral signatures allow for the extraction of information concerning the land-use and land cover, emissivity, surface temperature and energy flux (Gumindoga, 2010). Land-use and land cover changes can be analyzed over a period of time using Landsat Multi Scanner (MSS) data and Landsat Thematic Mapper (TM) data by image classification techniques (Gumindoga, 2010). The combination of land-use and land cover from Landsat images and statistical census on land-use data have proved more successful than only using vegetation indices in studies of land-use change where urban expansion processes are taking place. In studying land use and land cover changes, GIS and remote sensing techniques are important tools in monitoring and assessment of their dynamics. This is determined by production of geospatial components for land features and natural resources based on time series imagery. Variation in temporal distribution of land cover due to land use practices helps in monitoring and assessing the environmental degradation (Kok & Veldkamp, 2001).

2.4 Image Classification

The selection of image classification scheme is to ensure that it represents the features as in true ground brightness value of each pixel. Visual and statistical examination of the images is used to assess the contamination of the scenes by factors such as clouds and other atmospheric conditions. Reducing and eliminating these factors can be costly in terms of time and therefore money and can result in the removal of useful image information. Some of the preferred selection classification include per pixel and objected based classification (Jensen, 2015).

2.5 Nitrogen and Oxygen Isotopes as Environmental Tracers

There are two stable isotopes of nitrogen namely ^{14}N and ^{15}N. There is a wide range of oxidation numbers exhibited by the nitrogen compounds ranging from +5 (NO_3) to -3 ($NH4^+$). This also offers wider isotopic compositions. The average abundance of ^{15}N in air is constant whereby ^{15}N / ^{14}N = 1/272. Isotope values are reported in per mil (‰) relative to atmospheric nitrogen and standard mean ocean water (SMOW) for oxygen isotopes.

The isotopic composition of $\delta^{15}N$-Nitrate and $\delta^{18}O$-Nitrate for different materials have distinct signatures hence can be applied to fingerprint the sources of nitrate water systems (Aravena *et al.*, 1993; Kendall & McDonnell, 1993). According to Widory *et al.* (2004), the $\delta^{15}N$ values in the

nitrate originating from sewage ranges between 4.3 and 17.4‰; for synthetic fertilizers, $\delta^{15}N$ values are similar with the values of atmospheric nitrogen that is from -4 to +4‰. Higher values of $\delta^{15}N$-NO_3^- are found in manure and sewage, they range from +10 to +22‰ for manure while that of sewage ranges from +6.7 to 18.2‰.

Since values of nitrate originating from different sources may overlap, δ^{18} O-Nitrate may be applied as additional parameter to aid in distinguishing between these sources (Aggarwal *et al.,* 1998; Kendall & Aravena, 2000; Widory *et al.,* 2004). The origin of oxygen in $\delta^{18}O$-Nitrate may be atmospheric oxygen or groundwater oxygen or both. This creates fluctuations in the values of $\delta^{18}O$-Nitrate. Nitrate originated from atmospheric oxygen have values ranging from +20 to +70‰. Fertilizers' values of $\delta^{18}O$-Nitrate usually range from +18 to +26‰ and are usually caused by fractionation during manufacturing processes (Aggarwal *et al.,* 1998).

2.6 Application of Stable Isotopes in Tanzania

The $\delta^{5}N$-Nitrate and $\delta^{18}O$-Nitrate isotopes have been applied separately or in combination to identify sources and transformation of nitrate in groundwater in Tanzania (Elisante & Muzuka, 2016a; Nkotagu, 1996). According to Elisante and Muzuka (2016a), nitrate in groundwater along the slopes of mount Meru was derived from sewage systems, animal manure and poor sanitation. High NO_3^- concentration in the Makutupora basin was inferred to be largely derived from the sewage effluents (Nkotagu, 1996; Rwebugisa, 2008).

In the southern east coast of Tanzania, $\delta^{18}O$ and $\delta^{2}H$ have been used to assess the origin of recharge and groundwater evolution. It was reported that rivers, deep wells and shallow wells were recharged by precipitation (Bakari *et al.,* 2012). Also, residence time of water in deep aquifers was determined using radiogenic carbon. In Kilimanjaro, the surface water (rivers and lakes) were recharged with shallow groundwater. At high elevated areas water sources were recharged by groundwater, precipitation and ice melt from the peak of a mountain however the concentration of nitrate in some boreholes was high indicating presence of anthropogenic water contamination (Mckenzie *et al.,* 2010).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area Description

Babati town is an administrative headquarter of the Manyara region, northern Tanzania. It lies between latitudes 3^0–40^0 S and longitudes 35^0–36^0 E (Fig. 1). One of the most conspicuous landmarks of Babati town is Lake Babati. Lake Babati has diverse species of fish and water birds and is known to be home to a sizeable population of hippos and other wild ungulates. The lake is a source of water for various economic and domestic activities. In the studied area, volcanic soils are dominant and range from sandy-loamy to clay and alluvial soils. However, alkaline soils may also be present in the lowlands such as those around Lake Babati.

The climate is warm and relatively wet with mean annual precipitation of 831 mm. The mean annual temperature is 20.2℃. The area's lithology was formed during the upper Mesozoic era, sedimentary rocks overlie Karoo system and Precambrian basement. These rocks comprise mainly of sandstone, limestone, shale, marl and local evaporates. They are found in rift valley and along the coast of Tanzania (Sangea, 2016). Agriculture and animal keeping are the primary livelihood activities in the study area. Small holder farming includes maize, sesame, sunflower, hortculture crops and legumes,in addition to small-scale agriculture, zero grazing animal (cattle, goats, ships) husbandries are also practiced whereby their manure are applied in the farms together with synthetic fertilizers. Furthermore the recent study pointed out poor sanitation as the one major environmental and health challenge in the area (Pantaleo *et al.*, 2018b; URT, 2014).

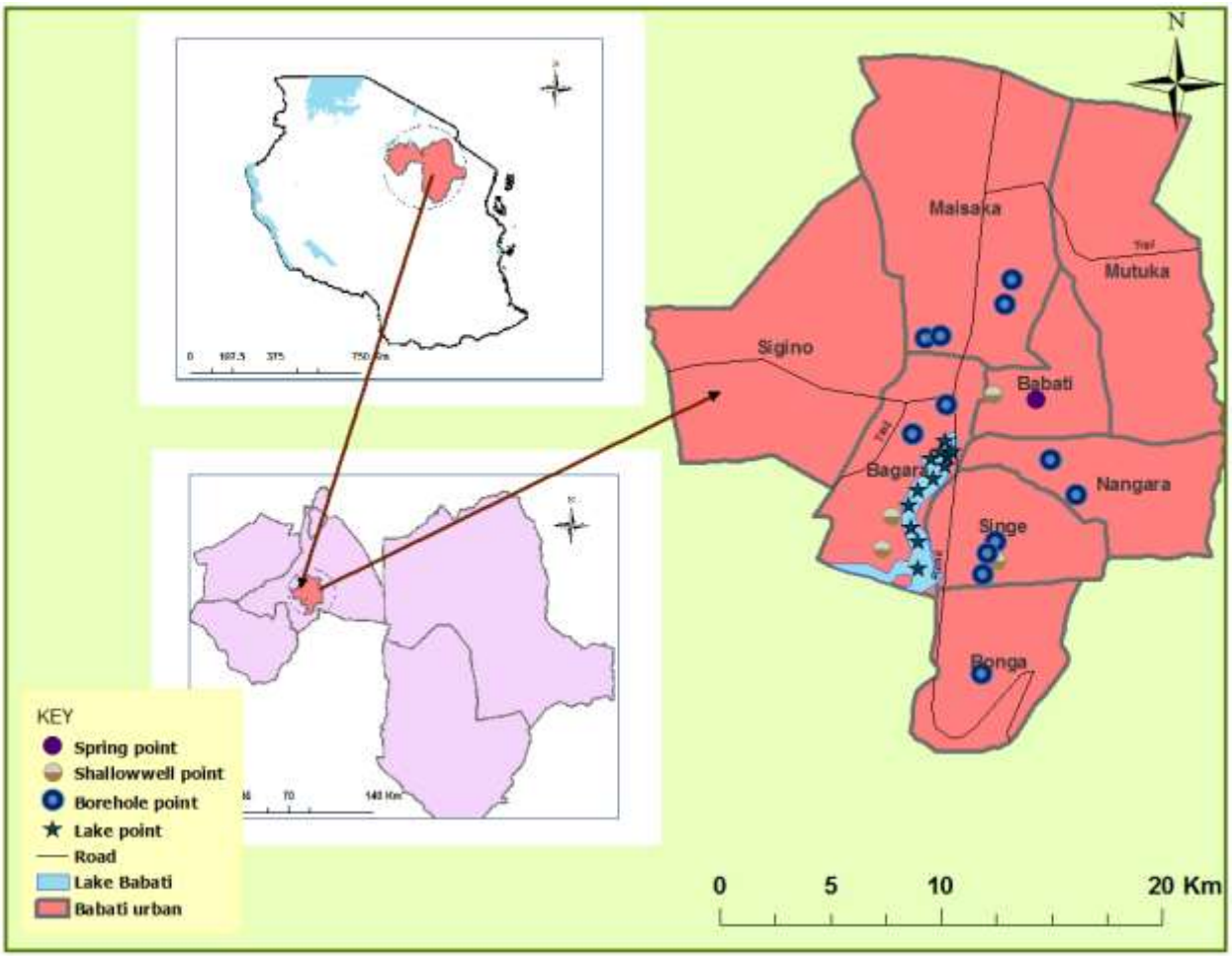

Figure 1: **Map of Tanzania (top left) indicating Manyara region (bottom left). Babati town and the respective sampling locations are shown on the right**

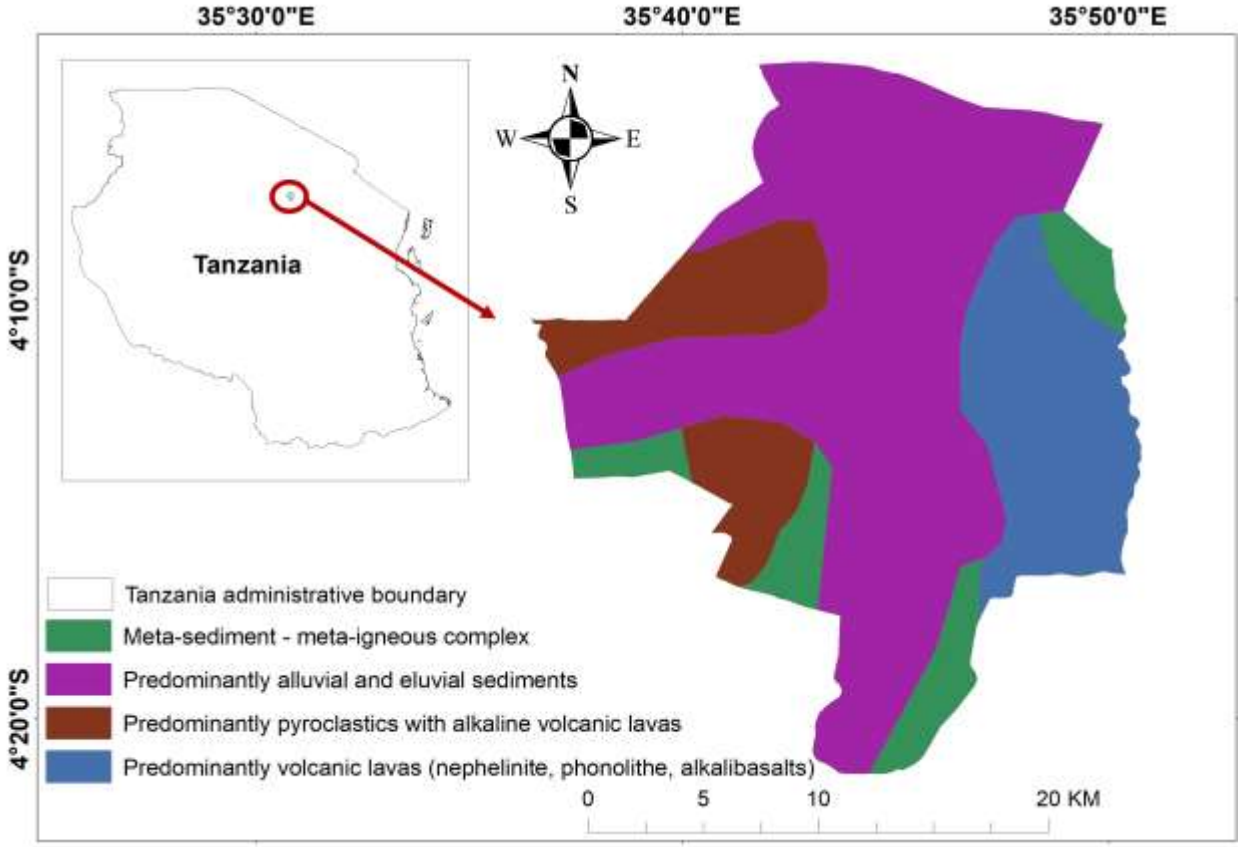

Figure 2: The geological map of Babati town

3.2 Water Samples Collection and Analysis

Water samples were collected in a prewashed polythene bottles from groundwater sources, spring and Lake Babati vertically and laterally in Babati Township during wet season (March to April). Groundwater samples were collected from various wards located in Babati town. These wards are Maisaka, Mutuka, Babati, Nangara, Singe Bonga and Bagara. Each bottle was rinsed three times with the water to be collected before sampling. The DO, Ph, temperature, TDS and EC were measured on site using Eijkelkamp 18.52 SA Model (pH/ mV/EC/T/sal/TDS/DO) multimeter. Water samples from Lake Babati were collected by using a water sampler. Water samples from boreholes were collected after pumping to allow the substitution of stagnant water by fresh water from the aquifer. All water samples were filtered through 0.45 µm filter paper using a hand pump. Samples for cations analysis were acidified with nitric acid on site to pH < 2 to prevent precipitation of cations and water. Water samples for anions were acidified with sulphuric acid to pH < 2 then the samples were kept in ice boxes and transported to NM-AIST laboratory where they were stored in refrigerator until analysis.

Water samples for isotopic analysis of nitrate were stored in HDPE bottles. Pretreatment of these samples was performed by addition of sulfamic acid at pH of 1.7 so as to reduce nitrite to N_2. Water samples were then neutralized with sodium hydroxide prior to isotope analysis (Granger &

Sigman, 2009). The samples were transported to University of waterloo in Canada for ∂^{15}N and ∂^{18}O detection through Trace Gas Ratio Mass Spectrometer (TG - TRMS).

The decision on the proportion of wells in the area was guided by the number of wells available and the human population density available. Moreover, the sites were chosen due to easy accessibility and they also reflect different activities in the catchment which could affect water quality situation in the area.

3.3 Image Acquisition and Pre-Processing

Three Landsat images were utilized in this study. Landsat 5 TM images captured on 02/01/1997, Landsat 7 ETM+ images captured on 02/01/2008 and Landsat 8 OLI images captured on 17/2/2017. More information about satellite images used for the present study is shown in Table 1. Remote sensing imagery for the study area for 1997, 2008 and 2017 were downloaded from the USGS Earth Explorer for the Babati town to examine land use changes over the past 20 years.

Table 1: Satellite data sources and detailed information for the analysis of LULC in the study area

Satellite	Sensor	Spatial resolution (m)	Path/Raw	Date	Source
Landsat 5	TM	30 x 30	168/ 63	02/01/1997	USGS
Landsat 7	ETM+	30 x 30	168/ 63	02/01/2008	USGS
Landsat 8	OLI	30 x 30	168/ 63	17/02/2017	USGS

Satellite images required pre-processing to ensure that the primary object could be established into a more direct affiliation between acquired data and biophysical phenomena (Rawat & Kumar, 2015). This pre-process was accomplished using ArcGIS Version 10.1 for georeferencing, mosaicking, and sub-setting of the image for the area of interest (AOI). Landsat 8 images underwent spatial sharpening using the panchromatic bands which resulted in images with a 30 m resolution. Further image processing analysis was carried out using ENVI 5.0. The image was displayed in natural color composite using a band combination of 3, 2, and 1 for Landsat 5 TM and 5, 4, 3, and 2 for Landsat 7 and Landsat 8. Maximum likelihood supervised classification was performed using several selected regions of interest (ROIs) based on defined classes which were agriculture, built-up area, water, bare lands and forests area as shown in Table 2.

Table 2: Classes defined according to the basis of supervised classification

No.	Class name	Description
1	Built up area	Including all residential, commercial, industrial and transportation (tarmac)
2	Agricultural land	All cultivated lands
3	Water	Including all water bodies (rivers, lakes, streams canals and reservoir).
4	Forests	All forested lands
5	Bare lands	All lands that are exposed to soil and barren areas influenced by human.

3.4 Accuracy Assessment

Land use maps obtained from image classification usually contain some errors. Therefore, it is very important to assess the accuracy of the obtained classification results (Foody, 2002). This is a quantitative assessment of how effectively the pixels were sampled into the correct land cover classes. The accuracy assessment of an image classification was performed by creating the classification error matrix. In this confusion matrix, classification results were compared with ground truth data acquired during fieldwork. This was done by picking the menu item classifier>accuracy assessment, then importing the ground coordinates of the ground truth samples from an Excel file which was already saved in text format. According to Coppin and Bauer (1996), the accepted classification results should normally be > 70%. Table 3 shows the accuracy assessment results for the year 1997, 2008 and 2017 for image classification.

Table 3: Accuracy assessment results for Landsat images for years 1997, 2008 and 2017

Year	1997		2008		2017	
Classes	Accuracy (%)	Producer Accuracy (%)	Accuracy (%)	Producer Accuracy (%)	Accuracy (%)	Producer Accuracy (%)
Built up area	91.18	81.58	91.18	81.60	88.57	83.80
Agriculture	84.00	85.71	84.00	85.70	84.00	87.50
Water	91.30	93.33	91.30	93.30	91.67	91.70
Forests	83.33	86.21	83.33	86.20	84.85	80.00
Bare lands	84.00	87.50	85.19	84.20	83.33	90.90
Overall accuracy	87.16		86.55		86.51	

3.5 Land Use Change Detection Analysis

The statistics from classified land use and land cover maps of 1997, 2008 and 2017 were used to detect the changes occurred in the period of 20 years. Change detection involved finding the quantities of the land use land cover changes, locations where the changes occurred, and the type

of changes happened at a certain period. In the classification process, quantitative changes were detected by comparing successive pairs of classified maps by subtracting the quantities of the current land use class from the quantities of the past land use class. Through the change detection, deep understanding in terms of anthropogenic interference in the land use and land covers of an area was possible and facilitated the understanding of suitable environmental protection strategy. The transformation of bare lands and native vegetation to agriculture and human settlements has significantly increased due to the human well-being at the expense of the degrading the water quality. The cultivated land and built up area have shown the negative impacts on water quality within the area and being the sources of nitrate in surface and groundwater.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Land Use and Cover Change in the Study Area

The extent of LULC changes from 1997, 2008 and 2017 have been summarized in Table 4 and Fig. 3. The LULC change detection map for: (a) 1997, (b) 2008 and (c) 2017 in Babati town are shown in Fig. 4. The data shows the land use type in 1997 for built-up area was 65 km^2 (14.4%), agriculture was 78 km^2 (17.3%), water was 8 km^2 (1.8%), forest was 73 km^2 (16.2%) and bare land was 227 km^2 (50.3%). In 2008, the built-up area had doubled to 130.4 km^2 (28.9%) whereby agriculture land also doubled up to 182.9 km^2 (40.6%) respectively. However, the area covered by water had reduced 7.5 km^2 (1.7%); forest cover also reduced to 57.9 km^2 (13.2%) and bare land reduced by a factor of three to 70.2 km^2 (15.6%). Data from 2017, indicate that the built-up area and agriculture land maintained the highest proportion, occupying 228.8 and 98.7 km^2 (50.7% and 21.9%), respectively. The area occupied by water bodies has been reduced to 7.4 km^2 (1.6%) whereas the forest area seems to have slightly increased to 63.1 (14%) km^2 probably due to recent forest conservation efforts run by both the government and private sector. On the other hand, bare land has shrunk by a factor of four from its 228.8 km^2 of 1997 to a mere 53.2 km^2 (11.8%) probably due to increasing population and demand for settlement areas. These changes may have negative impacts on the quality of water and water sources. Similar findings were reported by Wilson (2015).

Table 4: A summary of LULC change in Babati town from 1997, 2008 and 2017 satellite information

LULC category	Area (km^2)			Percent change (%)		
	1997	2008	2017	1997	2008	2017
Built-up area	65	130.4	228.8	14.4	28.9	50.7
Agriculture	78	182.9	98.7	17.3	40.6	21.9
Water	8	7.5	7.4	1.8	1.7	1.6
Forest	73	59.5	63.1	16.2	13.2	14
Bare land	227	70.2	53.2	50.3	15.6	11.8
Total	451	451	451	100	100	100

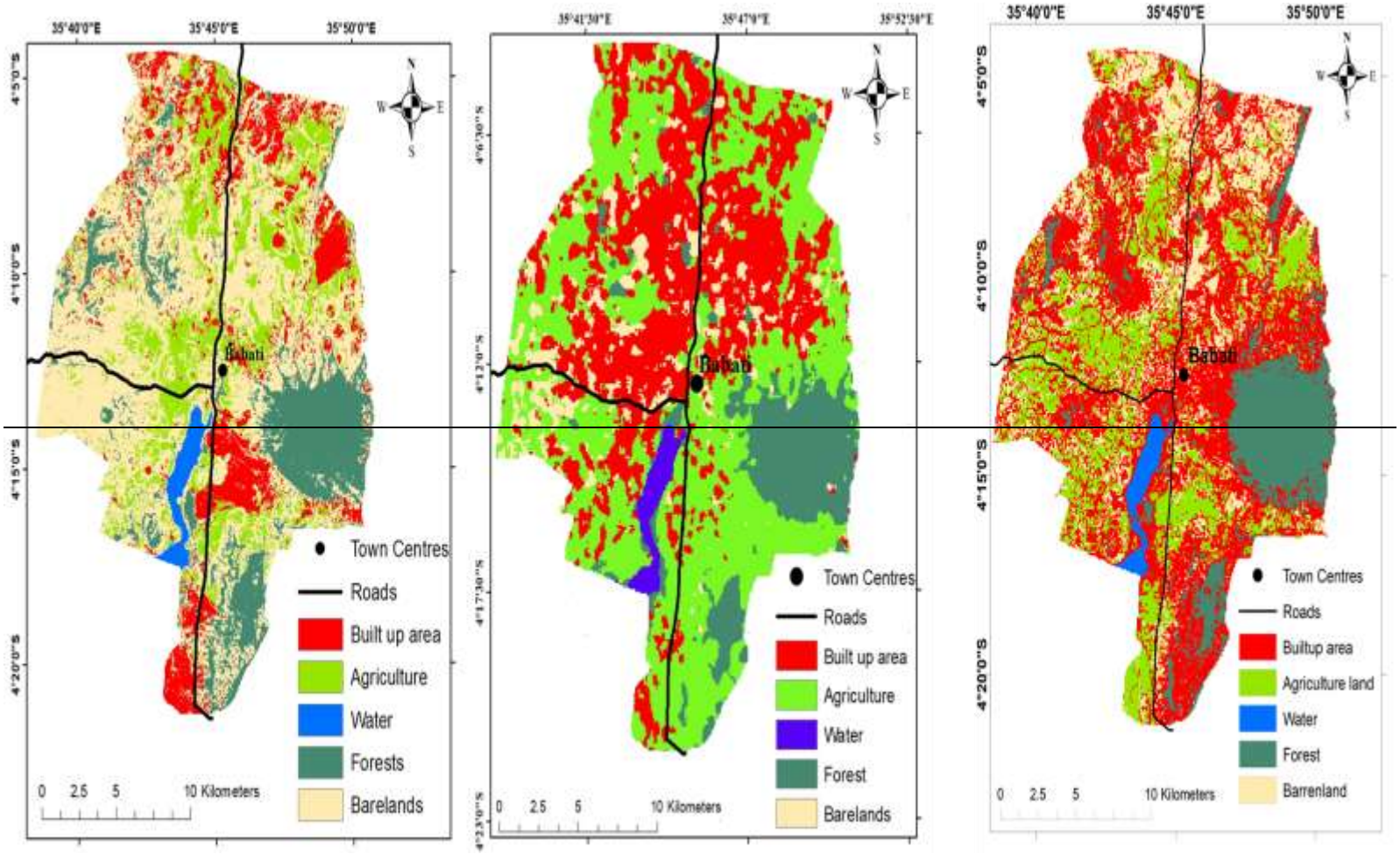

Figure 3: LULC change detection map for (a) 1997 (b) 2008 (c) 2017 in Babati town

The presence of nitrate and other nutrients at high levels in natural waters usually indicates that there is anthropogenic influence on the water quality (Salvado *et al.*, 2006). In the studied area, agriculture is a major economic activity followed by animal keeping but also use of pit latrines is common in some households. These may have contributed to the pollution risk on water resources in the area because of the possibility of pollutants being released from both point and nonpoint sources. Elevated levels of nitrate were detected in some boreholes and shallow wells located in densely populated areas where use of pit latrines, application of fertilizer and animal husbandry were commonly practiced. Similar cases of groundwater pollution with high levels of nitrate have been reported in Babati and other parts of Tanzania (Elisante & Muzuka, 2017; Nkotagu, 1996; Pantaleo *et al.*, 2018a). The sampling point BH3 with a nitrate concentration of 54.5 mg/L was in a lowland area surrounded by maize farms where fertilizers were highly applied. This implies that the nitrate may be originated from anthropogenic activities like application inorganic fertilizers in farms. However, water samples from the Lake Babati revealed low levels of nitrate below the background levels 10 mg/L.

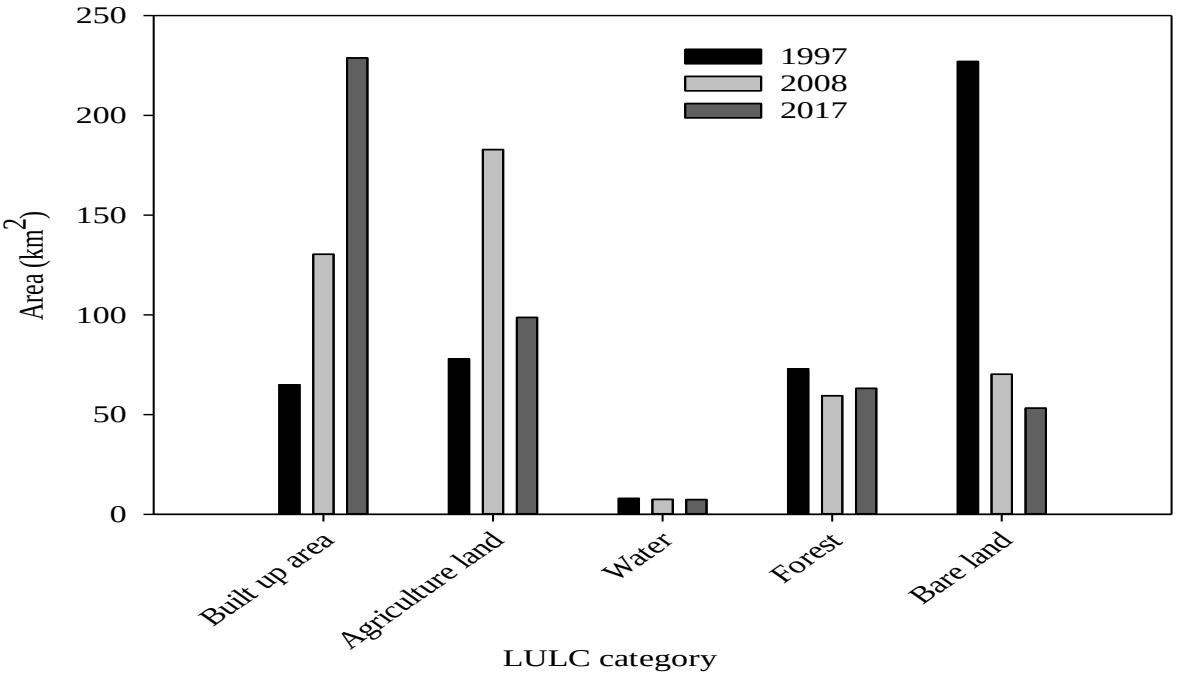

Figure 4: LULC change in Babati town

Table 5: Physical, chemical and isotopic composition parameters measured in the groundwater samples

Sample	pH	EC	Temp	NO_3^-	SO_4^{2-}	HCO_3^-	Cl^-	Mg^{2+}	K^+	Na^+	Ca^{2+}	Fe^{2+}	Cu^{2+}	Zn^{2+}	Pb^{2+}	Mn^{2+}	Cd^{2+}	$\delta^{15}N$-NO_3^-	$\delta^{18}O$-NO_3^-
	-	µS/cm	^0C	mg/L[a]														‰	
BH 01	7.56	848	25.7	24	37	221.8	106.07	203.4	0.06	5.4	36.6	0.03	0.04	0.1	0.01	BDL	BDL	3.2	2.7
BH 02	7.44	982	25.3	8.9	46	113.6	94.29	68	0.36	8.9	261.5	1.93	0.35	BDL	0.01	BDL	0.02	20.1	8.6
BH 03	7.48	1704	25.9	54.5	39	120.6	19.31	9	0.5	10.1	275.5	0.28	0.47	0.12	0.12	BDL	0.01	3.5	2.1
BH 04	7.36	1630	26.4	7.2	20	189.3	14.22	130	1.3	14.7	121.4	0.04	0.02	BDL	BDL	0.01	BDL	8.6	0.2
BH 05	7.52	1418	28.1	5.3	45	272.1	43.28	21	0.4	10.3	217	1.19	0.39	0.06	BDL	0.01	0.01	10.97	2.84
BH 06	7.81	1372	26.3	4.2	23	164.7	34.83	15	0.6	10.6	180.5	0.28	0.62	BDL	0.04	BLD	0.05	12.4	3.24
BH 07	7.52	821	23.1	4.3	2	223.21	12	40	0.8	8.9	143.6	0.07	0.04	0.02	0.01	0.01	0.01	16.22	4.8
BH 08	7.36	790	26.4	9.7	3	279.8	25.35	37.6	0.4	7.3	166.8	0.08	0.07	0.02	BDL	0.01	0.01	10.64	2.6
BH 09	7.33	1007	26.1	11.3	4	174.4	16.15	29	0.1	10.4	206.2	0.09	0.04	BDL	0.04	0.02	0.01	-	-
BH 10	7.47	2007	25	5.5	25	162.8	51.21	5.5	0.2	9.5	7	0.06	0.45	BDL	0.01	BDL	BDL	15.53	7.45
BH 11	7.36	2370	22.9	3.6	36	168.4	35.7	108.4	1.1	21.9	53.2	0.04	0.01	BDL	BDL	BDL	BDL	-	-
BH 12	7.41	657	25.1	7.6	1	188.9	6.79	51.4	0.7	6.1	66	0.04	BDL	0.05	BDL	BDL	BDL	-	-
SW 01	7.53	1293	25.2	2.9	3	122.7	18.5	170	1.2	11.4	158.2	0.04	0.04	0.03	0.02	0.01	0.02	-	-
SW 02	7.38	1393	24.5	20.8	5	112.5	29.42	164	0.7	11.7	152.5	0.06	0.03	0.01	0.02	0.01	0.03	2.4	19
SW 03	7.04	1849	23.9	11.6	13	107.9	34.2	82	0.7	17.1	314.2	0.06	0.09	0.01	0.01	0.01	BDL	19.3	4.24
SW 04	7.34	701	25.1	6.4	3	118.6	23.49	3	0.5	6.3	101	0.05	0.05	0.05	0.02	0.01	0.01	18.7	5.3
SPR	7.26	1278	24.3	1.7	1	78.4	6.5	4	0.1	7.2	25.9	0.01	0.01	BDL	BDL	BDL	BDL	-	-

[a]BDL = Below detection limit

Table 6: Physical, chemical and isotopic composition parameters measured in the surface water samples

	pH	EC	Temp	NO_3^-	SO_4^{2-}	HCO_3^-	Cl^-	Mg^{2+}	K^+	Na^+	Ca^{2+}	Fe^{2+}	Cu^{2+}	Zn^{2+}	Pb^{2+}	Mn^{2+}	Cd^{2+}	$\delta^{15}N$-NO_3^-	$\delta^{18}O$-NO_3^-
Sample	**-**	**µS/cm**	**^{0}C**	**mg/L[a]**														**‰**	
LK 1	7.5	1063	23.4	1.7	1	181.2	9.97	64	0.7	26.36	57	0.08	0.04	0.03	BDL	0.01	BDL	1.78	1.5
LK 2	7.5	1063	23.4	1.4	1	133.8	8.21	60.9	0.9	26.2	59.1	0.07	0.04	0.04	0.01	0.01	BDL	-	-
LK3	7.6	1056	23.4	1.3	1	123.6	8.49	77	0.6	25	52.4	0.12	0.04	BDL	0.01	0.04	0.01	-	-
LK 4	7.6	1056	23.4	3.3	1	132.2	9.45	65	0.7	26.26	43.26	0.11	0.04	BDL	0.02	0.03	0.01	2.1	12.4
LK 5	7.39	1068	23.13	2.7	1	123.5	7.01	67	0.7	26.63	48.6	0.06	0.01	BDL	0.02	0.02	0.01	-	-
LK 6	7.39	1068	23.13	2.4	1	129.6	3.44	60.6	0.6	26.23	30.1	0.15	0.03	0.01	0.01	0.02	0.01	-	-
LK 7	7.37	1052	23.5	3.2	2	127.9	3.98	66.1	0.73	26.06	38.9	0.15	0.02	0.12	0.01	0.04	BDL	4.75	18.8
LK 8	7.65	1042	23.5	1.8	2	194.2	6.99	31.2	0.8	26.66	52.4	0.09	0.001	0.01	0.01	0.02	BDL	-	-
LK 9	7.65	1042	23.5	2.5	2	152.7	9.49	32.8	0.6	26.69	58.8	0.14	0.06	0.01	0.04	0.02	0.01	-	-
LK10	7.46	1048	23.3	1.2	1	182.6	11.9	23.8	1	25.53	65	0.09	0.05	0.03	0.02	0.03	0.01	12.6	6.72
LK11	7.46	1048	23.3	3.9	2	131.2	11.5	26.2	0.7	26.4	62.7	0.08	0.04	0.03	0.03	0.03	0.01	-	-
LK12	7.37	1054	23.2	2.1	1	175.4	2.49	55.6	0.8	38.4	40	0.07	0.01	0.01	BDL	0.02	BDL	-	-
LK13	7.7	1054	23.2	2.8	1	160.8	4.89	51.5	0.9	37.7	48.6	0.07	0.02	0.01	BDL	0.02	BDL	-	-
LK14	7.27	1044	23.3	4	1	121.5	2.49	51.5	0.7	36	51.6	0.08	0.01	BDL	BDL	0.02	0.02	6.63	4.62
LK15	7.7	1044	23.3	4.4	1	184.9	4.45	43.4	0.9	26.5	49.8	0.06	0.01	BDL	0.01	0.02	0.02	-	-
LK16	7.7	1039	23.5	2.7	2	174.2	1.99	57.8	0.7	25.9	57.8	0.06	0.01	0.04	BDL	0.03	BDL	-	-
LK17	7.7	1039	23.5	1.2	2	193.2	1.23	80	0.53	25.93	29	0.06	0.03	0.04	BDL	0.03	0.03	2.9	16.3
LK18	7.39	1019	23.8	2.6	1	179.1	3.35	45.1	0.43	25.3	47.6	0.09	0.02	0.01	0.01	0.02	0.02	-	-
LK19	7.39	1019	23.8	3.3	3	139.6	3.01	19	0.6	25.73	89	0.07	0.03	BDL	0.01	0.02	0.02	-	-
LK20	7.45	932	23.3	3.6	4	101.6	0.48	43.8	0.33	23.4	59.5	0.14	0.04	0.02	0.02	0.02	0.02	-	-
LK21	7.31	750	22.9	1.3	4	198.7	0.99	44.5	0.8	27.76	10.7	0.16	0.03	0.01	0.02	0.02	0.02	3.6	21.9

[a]BDL = Below detection limit

4.2 Levels of Physico-Chemical Parameters

4.2.1 Onsite Parameters

Understanding the physico-chemical quality of surface and groundwater is essential as it is an important factor in determining water suitability for human and environmental application. Table 5 and 6 contain results of the physico-chemical analyses. Temperature of groundwater varied from 22.9°C to 28.1°C with a mean value of 25.2 ± 0.3°C whereby BH5 showed the highest temperature of 28.1°C (elevation 1294 m.a.s.l.) and the lowest temperature in groundwater was 22.9ºC (elevation 1383 m.a.s.l.). This slight variation in water temperature may be attributable to the differences in altitude rather than aquifer type. Surface water temperature varied from 22.9°C to 23.8°C with a mean value of 23.4 ± 0.1°C (Table 6). The pH of groundwater ranged from 7.1 to 7.8 with a mean value of 7.4 ± 0.1 (Table 5) while for surface water the pH varied from 7.3 to 7.7 with mean value of 7.5 ± 0.1 (Table 6). These pH values fell within the normal pH of the natural aquatic environments. The EC of groundwater varied from 657 to 2370 µS/cm, with a mean value of 1301.18 ± 119.74 µS/cm (Table 5). For surface water, the EC ranged from 750 to 1063 µS/cm with a mean value of 1027.43 ± 15.13 µS/cm (Table 6). Similar observation was reported by Chacha *et al.* (2018).

4.2.2 Major Cations

In groundwater, calcium values varied from 7.0 to 314.2 mg/L with a mean value of 146.3 ± 90.9 mg/L (Table 5) while in surface water, calcium varied from 10.7 to 89.0 mg/L with a mean value of 50.1 ± 15.7 mg/L (Table 6). High levels of Ca in groundwater systems may be attributed to the dissolution of carbonate and gypsum rocks (Chenini *et al.*, 2010). The desirable limit of calcium in drinking water as specified by WHO is 75 mg/L; it was observed that in eleven groundwater samples Ca levels had exceeded the limit set by WHO. Magnesium concentration in groundwater varied from 2.6 to 203.4 mg/L with a mean value 67.1 ± 65.2 mg/L while in surface water it varied from 19.0 to 80.0 mg/L with mean value of 50.8 ± 17.2 mg/L. According to WHO (2011) the desirable limit of Mg is 50 mg/L meaning that eight groundwater samples, equivalent to 47%, exceeded the WHO limit. High levels of Ca and Mg are indicative of water hardness and imply that some water sources in the studied area may not be potable. This means water must contain sufficiently low levels of dissolved salts. Similar to Ca, high levels of Mg in groundwater may also be linked the dissolution of carbonate minerals and gypsum rocks and, most probably, the dissolution of nesquehonite ($MgCO_3 \cdot 3H_2O$) (Chenini *et al.*, 2010; Dong *et al.*, 2008). Sodium concentration in groundwater varied from 5.4 to 21.9 mg/L with a mean value of 10.5 ± 4.2 mg/L, while in surface water it varied from 23.4 to 38. 4 mg/L with a mean value of 27.7 ± 4.2 mg/L.

Potassium concentration in groundwater varied from 0.06 to 1.3 mg/L with a mean value of 0.6 ± 0.4 mg/L while in surface water it varied from 0.3 to 1.0 mg/L with a mean value of 0.7 ± 0.2 mg/L. A similar study was conducted in Chad Basin in Nigeria, whereby Ca-Mg-HCO_3 was traced to water recharge and its sources were connected to rainfall and dissolution of silicate minerals (Nur *et al.*, 2012). Thus, high levels of Ca^{2+} and Mg^{2+} in the present study could be linked to silicate minerals leached by weathering due to the action of weak carbonic acid (Nur *et al.*, 2012). In groundwater samples of the present study, Mg was significantly correlated to bicarbonate (r = 0.58, p = 0.014) whereas Ca had a good correlation with bicarbonate (r = 0.47, p = 0.05) (Table 7). This is probably an indication that the groundwater of Babati and its suburbs are of Ca-Mg-HCO_3 type. This could also be the reason why water samples collected from Lake Babati indicated a significant correlation between Mg and bicarbonate (r = 0.54, p = 0.011) (Table 8).

4.2.3 Major Anions

Nitrate concentration in groundwater ranged from 1.7 to 54.5 mg/L, with an average value of 11.5 ± 3.1 mg/L (Table 5, Fig. 5). Only five groundwater samples (BH1, BH3, BH9, SW2, and SW3) exceeded the background limit which is 10 mg/L. Surface water showed relatively low concentrations of nitrate ranging from 1.2 to 4.4 mg/L with an average value of 2.5 ± 0.2 mg/L (Table 6). Higher levels of nitrate in drinking water systems are known to cause health and aesthetic problems. Land use change enhances the nitrate concentration in water sources rather than soil and bed rock. For instance agriculture releases a significant amount of nutrients into water sources, but also built up areas increase the run off volume and washing out of nutrients. Surface water showed relatively low concentration of nitrate ranging from 1.2 to 4.4 mg/L with average value of 2.5 ± 0.2 mg/L (Table 6, Fig. 6). This may be due to some reactions such as denitrification process that attenuate nitrate in a lake system (Aravena & Robertson, 1998).

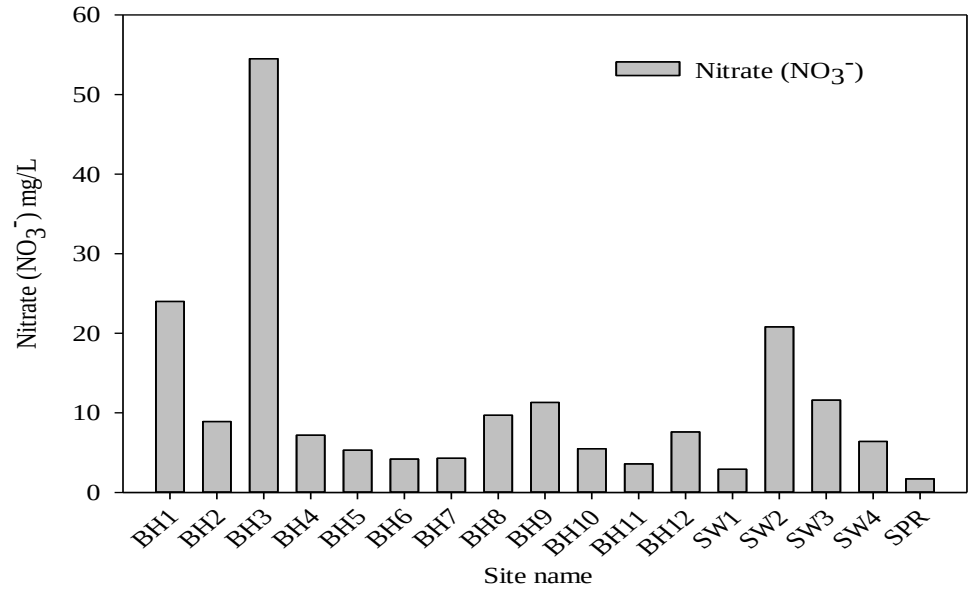

Figure 5: Levels of nitrate in groundwater

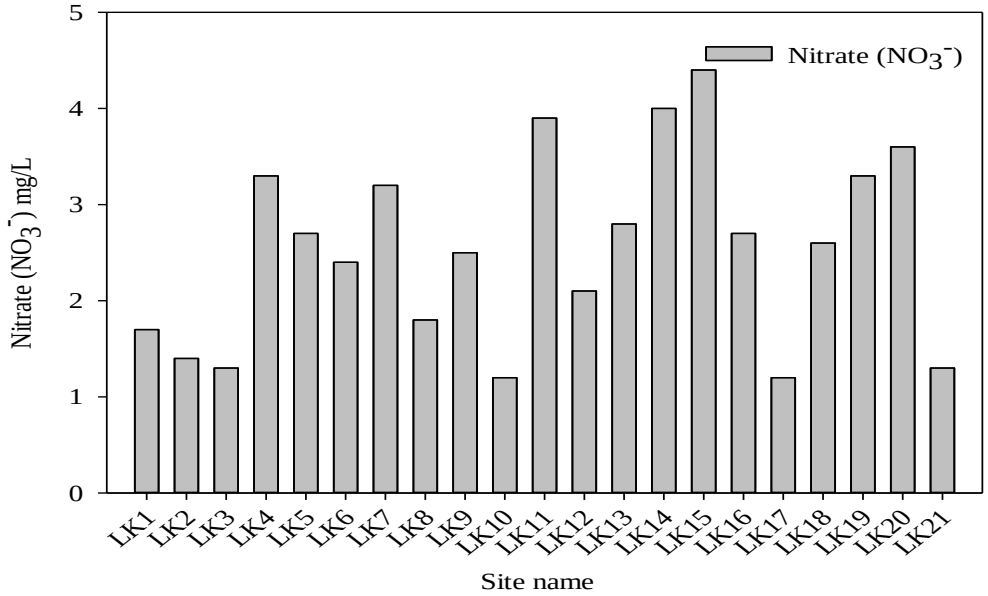

Figure 6: Levels of nitrate in surface water

The concentration of sulfate was low compared to the WHO guideline (250 mg/L). The highest concentration of sulfate detected in groundwater was 46 mg/L and the lowest was 1.0 mg/L with the mean value of 18.0 ± 4.1 mg/L (Table 5), whereby in surface water the mean value was 1.7 ± 0.2 mg/L; highest concentration was 4.0 mg/L and the lowest was 1.0 mg/L (Table 6). Chloride concentration was higher in groundwater samples than in surface water samples whereby the maximum chloride value in groundwater was 106.1 mg/L, and the lowest was 6.5 mg/L with the mean value of 34.6 ± 6.9 mg/L (Table 5). In surface water, chloride ranged from 0.5 to 5.6 mg/L with average value of 5.6 ± 0.8 mg/L (Table 6). Chloride over the anions could be attributed due to application of chemical fertilizers. Chloride could have not resulted from evaporate since the source of evaporate was unlikely in the area (Kelly *et al.,* 2012). Bicarbonate in groundwater ranged from 279.4 to 78.4 mg/L with average value of 166.0 ± 13.9 mg/L (Table 5) whereby in

surface water it ranged from 101.6 to 198.7 mg/L with average value of 154.4 ± 6.5 mg/L (Table 6).

4.2.4 Trace Elements

Iron (Fe) concentrations in groundwater varied from 0.01 to 1.93 mg/L with a mean value of 0.27 ± 0.13 mg/L whereby BH2 and BH5 showed higher concentration of Fe than the aesthetic value set by WHO. In surface water, Fe varied from 0.06 to 0.16 mg/L with mean value of 0.095 ± 0.01 mg/L. All the analyzed surface water samples had iron concentrations within the aesthetic value set by WHO which is 0.3 mg/L. The concentration of Cu in groundwater ranged from 0.001 to 0.62 mg/L with a mean value of 0.2 ± 0.1 mg/L, while that of surface water varied from below detection to 0.06 mg/L with a mean value of 0.270 ± 0.005 mg/L. All the water samples were within the recommended WHO standard which is 2.0 mg/L for Cu (WHO, 2011b).

For Zn, the concentrations in groundwater ranged from 0.00 to 0.012 mg/L with a mean value of 0.280 ± 0.001 mg/L, while that of surface water ranged from below detection to 0.12 mg/L with a mean value of 0.020 ± 0.005 mg/L. Generally, the concentration of zinc can mainly be associated with agriculture (Land use) through use of insecticides and fungicides. The permissible limit of zinc in drinking water is 3.0 mg/L (WHO, 2011a). The concentration of lead (Pb) in groundwater samples ranged from below detection to 0.04 mg/L with mean value of 0.020 ± 0.007 mg/L while that of surface water ranged from below detection to 0.04 mg/L with mean value of 0.012 ± 0.002 mg/L. According to WHO (2011) the permissible limit of lead in drinking water is 0.01 mg/L. The Pb is a known neurotoxin, especially to children aged < 5 y, the levels of Pb in some of the samples seem to be alarming as they had exceeded the WHO limit. Lead is a cumulative poisonous metal. To children below 5 years and fetus lead can cause adverse health effects like brain damage, renal, endocrine and reproductive disorders. The source of lead in drinking water is anthropogenic which include lead pipes or lead service lines, faucets and fixture. A study conducted in Glasgow showed high levels of lead in young children, hence there should be regular checkup of blood lead levels (Watt *et al.*, 2000). Manganese concentrations in groundwater varied from below detection to 0.002 mg/L with a mean value of 0.006 ± 0.002 mg/L, and that of surface water varied from 0.010 to 0.004 mg/L with a mean value of 0.024 ± 0.002 mg/L. All the water samples were within the WHO indicative aesthetic value for Mn. The concentration of Cd in groundwater ranged from below detection to 0.050 mg/L with a mean value of 0.011 ± 0.003 mg/L while that of surface water it varied from below detection to 0.030 mg/L with a mean value of 0.011 ± 0.002 mg/L. The WHO permissible limit of cadmium in drinking water is 0.003 mg/L. All the water samples were above the WHO limit. These contamination results indicates that major proportion of the population in the study area is at risk

of cadmium toxicity as water samples from Babati town were highly contaminated with cadmium. These levels of trace elements found in the present study were lower than the levels found in the drinking water from wells in small scale mining in Ghana (Cobbina *et al.,* 2015) and were comparable to the levels reported by Ilyas and Sarwar (2003) in groundwater from Peshawar in Pakistan.

Table 7: Pearson correlation matrix for groundwater samples

	pH	**Temp.**	**EC**	**NO_3^-**	**SO_4^{2-}**	**HCO_3^-**	**Cl^-**	**Mg^{2+}**	**K^+**	**Na^+**	**Ca^{2+}**
pH	1										
Temp.	0.41	1									
EC	-0.159	-0.151	1								
NO_3^-	0.041	0.167	0.084	1							
SO_4^{2-}	0.316	0.381	0.412	0.329	1						
HCO_3^-	-0.12	0.111	0.05	0.165	0.008	1					
Cl^-	0.307	0.196	0.327	0.186	0.736**	-0.141	1				
Mg^{2+}	0.005	-0.144	0.063	0.069	0.066	0.583*	0.252	1			
K^+	-0.009	-0.264	0.323	-0.185	-0.123	0.166	-0.265	0.406	1		
Na^+	-0.302	-0.323	0.814**	-0.101	0.226	0.131	0.032	0.256	0.613*		
Ca^{2+}	-0.132	0.240	0.240	0.355	0.207	0.47*	-0.384	-0.116	0.0784	0.21	1

*Significant correlation. **High significant correlation. Significant *p*-value ≤ 0.05. EC/Na^+, p = 0.00001; SO_4^{2-}/Cl^-, p = 0.0008; HCO_3^-/Ca^{2+}, p = 0.05; HCO_3^- /Mg^{2+}, p = 0.0141; and K+/Na+, p = 0.009.

Table 8: Pearson correlation matrix for surface water samples

	pH	EC	Temp.	NO_3^-	SO_4^{2-}	HCO_3^-	Cl^-	Mg^{2+}	K^+	Na^+	Ca^{2+}
pH	1										
EC	0.319	1									
Temp.	0.044	0.162	1								
$N0_3^-$	-0.33	0.156	-0.372	1							
SO_4^{2-}	-0.06	-0.84**	-0.238	0.052	1						
HCO_3^-	-0.09	-0.02	-0.141	-0.022	-0.376	1					
Cl^-	-0.06	0.337	0.171	0.058	-0.156	-0.063	1				
Mg^{2+}	-0.02	0.281	-0.58*	-0.27	-0.344	0.544*	0.095	1			
K^+	-0.001	0.095	0.526	-0.17	-0.374	0.029	0.228	-0.15	1		
Na^+	-0.47	0.122	-0.18	0.116	-0.305	0.111	-0.187	0.045	0.371	1	
Ca^{2+}	0.504	0.71**	0.41	0.287	-0.043	-0.51*	0.041	-0.52*	-0.027	-0.18	1

*Significant correlation. **High significant correlation. Significant p-value $\leq$ 0.05. (a) Positive significant correlations for surface water: Ca^{2+}/EC, p = 0.009; HCO_3^-/Mg^{2+}, p = 0.011, and (b) Negative significant correlations for surface water SO_4^{2-} /EC, p = 0.0007; Temp/Mg^{2+}, p = 0.047; HCO_3^-/Ca^{2+}, p = 0.018; Ca^{2+}/Mg^{2+}, p = 0.016.

4.2.5 Water Types in the Study Area

Piper diagram grouped waters originating from different geological formations in Babati town in three hydro-chemicals faces based on their major cations and anions contents. The faces were Mg $(HCO_3)_2$, $NaHCO_3$ and $NaCl_2$ (Fig. 2). Majority of water sources were of $MgHCO_3$. The concentration of major cations in groundwater and surface water was in the following order $Ca^{2+} > Mg^{2+} > Na^+ > K^+$ (Tables 4 and 5). During infiltration, groundwater may dissolve the $CaCO_3$ and $MgCO_3$ found in water rocks to add up to the concentration of Ca^{2+} and Mg^{2+} in water (Dehnavi *et al.*, 2011). Results from the present study indicated that alkaline earth type of water (Ca^{2+}, Mg^{2+}) exceeded alkalis (Na^+, K^+) whereas weak acid (HCO_3^-) exceeded the strong acids SO_4^{2-} and Cl^- which may be indicative of slight hardness in all groundwater samples. Chemical composition of ground and surface water from the study area is largely influenced by the aquifer lithology than anthropogenic activities since there is no known geological source for chloride and sulphate was observed, sources for both ions might be derived from agricultural activities like application of fertilizers. This was further corroborated by the Pearson correlation values in Tables 7 and 8.

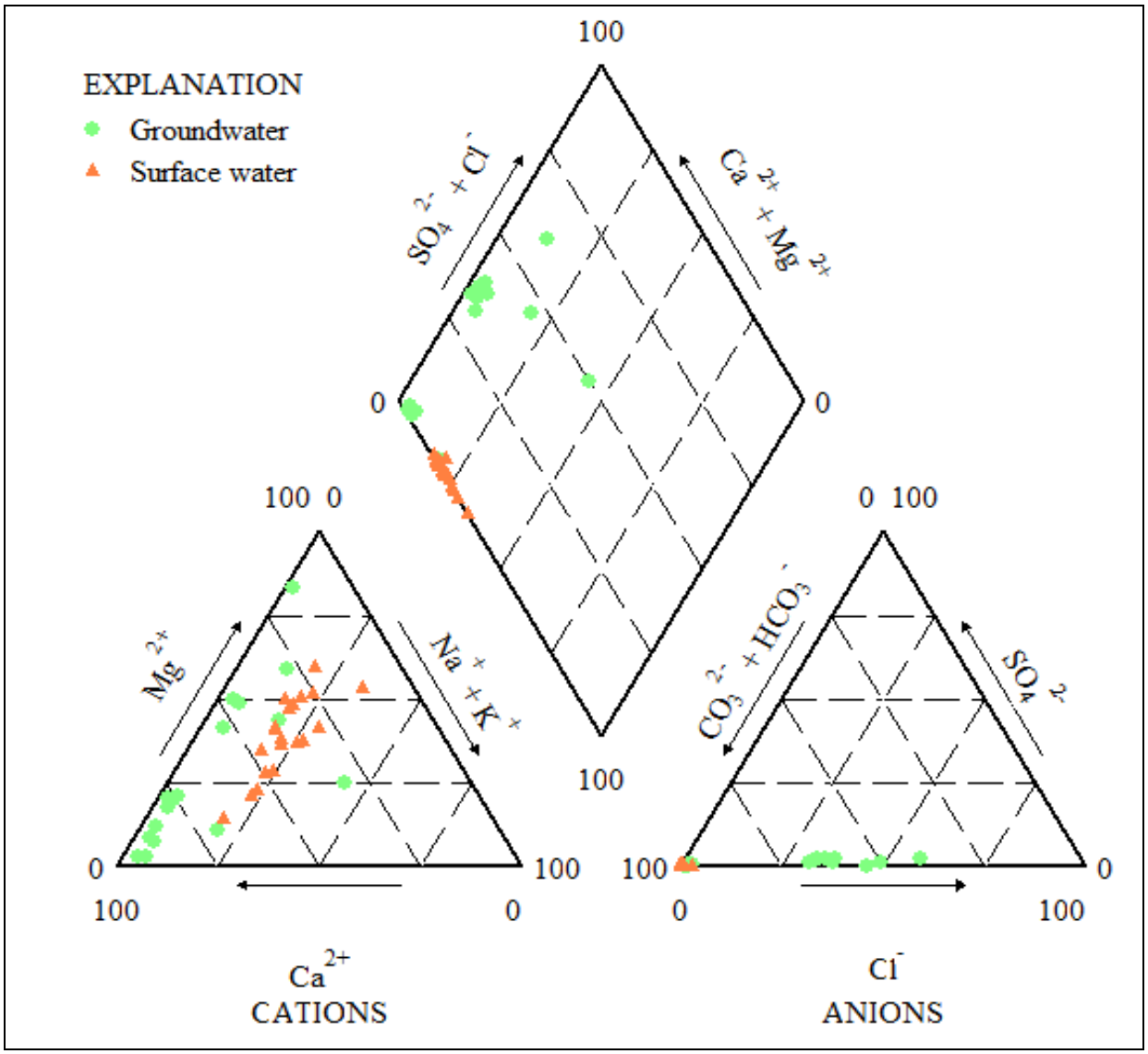

Figure: 7 **Piper diagram for hydro-chemical composition for surface and groundwater samples collected in the study area. The bottom left ternary shows the actions while right ternary shows the anions. The top diamond-shaped chart represents both anions and cations and distribution in the water samples**

A significant negative correlation between Ca^{2+} and HCO_3^- in surface water (Table 7; r = -0.51, p = 0.018) may indicate that Ca^{2+} was constantly being replaced by Mg^{2+} meaning that $MgCO_3$ or $Mg(HCO_3)_2$ were more dominant species rather than $CaCO_3$ or $Ca(HCO_3)_2$ (Jahnen-Dechent & Ketteler, 2012). This phenomenon is further proved by a significant negative correlation between Mg^{2+} and Ca^{2+} in surface water; with r = -0.52 and p = 0.016 (Table 7). It further follows that the solubility of $MgCO_3$ probably decreased with increasing surface water temperature and that is probably why Mg^{2+} was negatively correlated with temperature r = -0.58, p = 0.047; Table 7.

4.3 Isotopic Studies

The isotopic signature is the results of combined effects of N sources and environmental factors (Nikolenko *et al.*, 2018). The values of δ^{15} N-Nitrate in groundwater ranged from 2.4‰ to 20.1‰

with the mean value of 11.8 ‰ ± 1.8 ‰ (Table 5) while in surface water δ^{15}N-Nitrate ranged from 2.1 ‰.to 12.6 ‰ with the mean value of 4.9‰. ±1.4 ‰. Table 6 suggest that more than one source of groundwater nitrate contamination. High enrichment in δ^{15}N-Nitrate values (higher 18%) was observed in groundwater (BH2, SW3 and SW4) which may indicate denitrification and δ^{15}N-Nitrate values for nitrate from manure (+10 to +20) and sewage (+9 and + 19) (Aravena & Mayer, 2009; Kendall & Aravena, 2000). Elevated nitrate concentration (> 10 mg/L) (BH1=18‰, BH 3 =3.5‰, BH 9= 0.0‰ and SW 2=2.4‰) were probably associated with industrial fertilizers (Table 5). On the other hand, elevated concentration of nitrate in SW3 (19.3‰.), and BH8 (10.64‰.) were probably associated with manure and/or sewage disposal. Rivett *et al.* (2008) reported that of δ^{15}N-Nitrate values ranging between +6 and +10‰ depict a mixture of chemical fertilizer and manure. In this study δ^{15}N-Nitrate values probably indicating mixing of water with different sources of nitrate were observed in groundwater samples from BH16, BH7 and BH11 were likely result of mixing waters with nitrate from fertilizer, manure and soil N.

A plot of δ^{15}N-Nitrate against δ^{18}O-Nitrate values (Fig. 8) showed that manure/sewage and fertilizer affected most water sources. Groundwater samples from BH1 (24 mg/L), BH3 (54.5 mg/L) and BH8 (9.7 mg/L) showed an influence of nitrogenous compounds from sewage and or manure (Table 5 and Fig. 8). Furthermore, groundwater samples from BH 9 (11.3 mg/L and SW3 (11.6 mg/L showed an influence of nitrification of ammonium fertilizers while groundwater samples from SW2 (20.8 mg/L) showed an influence of nitrogenous fertilizer. Elevated concentration of nitrate in most water sources suggests that nitrification was dominant process (Fig. 8). Elevated concentration of nitrate is observed in aquifer systems underneath or in close proximity to anthropogenic activities such as agriculture, sanitation and waste disposal sites (Nishikawa *et al.*, 2018).

Surface water can receive groundwater inflow, recharge groundwater or both. Such movements of water between groundwater and surface water systems may lead to mixing of water qualities. Hence nitrate and other dissolved nutrients in surface water can be transferred to the connected groundwater system and vice versa.

The theoretical δ^{18}O-Nitrate values was calculated using δ^{18}O-Nitrate values reported for the study area as per Aravena and Mayer (2009). The range of δ^{18}O-Nitrate in ground and surface water was low, indicating nitrate derived from nitrification (-10 ‰ to + 10‰), fertilizers, manure and soil N (0.8‰ to 5.8‰). The main source of elevated nitrate concentrations (>10 mg/L in groundwater for BH2= 2.7 ‰, BH3 =2.1‰, BH8 = 2.6‰, BH9= 0.0‰ and SW3 = 4.24‰ were probably the nitrate derived from nitrification (-10‰ to +10‰), ammonium fertilizers, manure and soil N (0.8‰ to 5.8‰). Similar findings were reported by other scholars (Elisante & Muzuka,

2016b; Koh *et al.,* 2009; Pastén-Zapata *et al.,* 2014). On the other hand, the elevated level of nitrate in SW2 (19‰) was likely a result of contamination with nitrate from nitrate fertilizers or enriched due to denitrification.

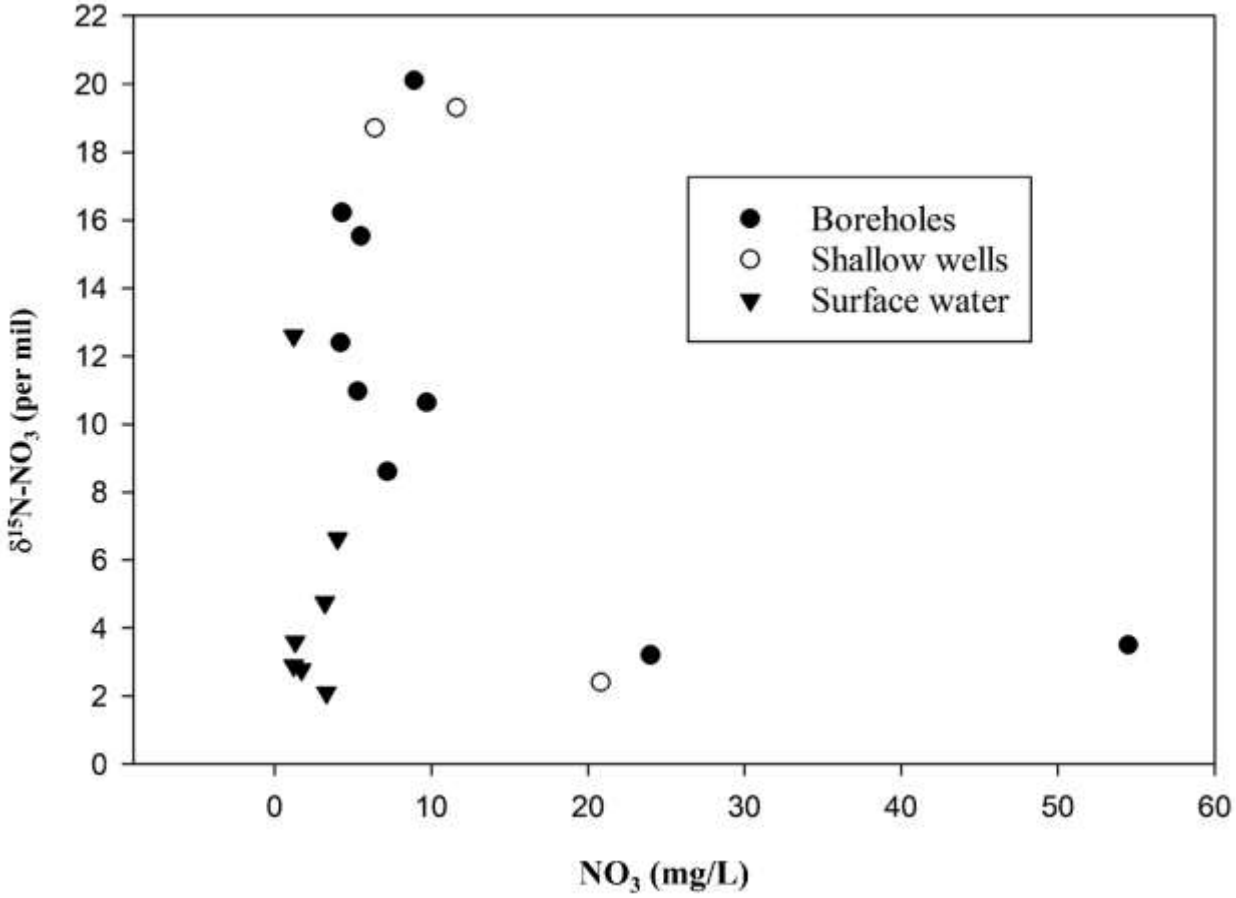

Figure 8: **δ^{15}N-nitrate values against nitrate concentration in groundwater and surface water**

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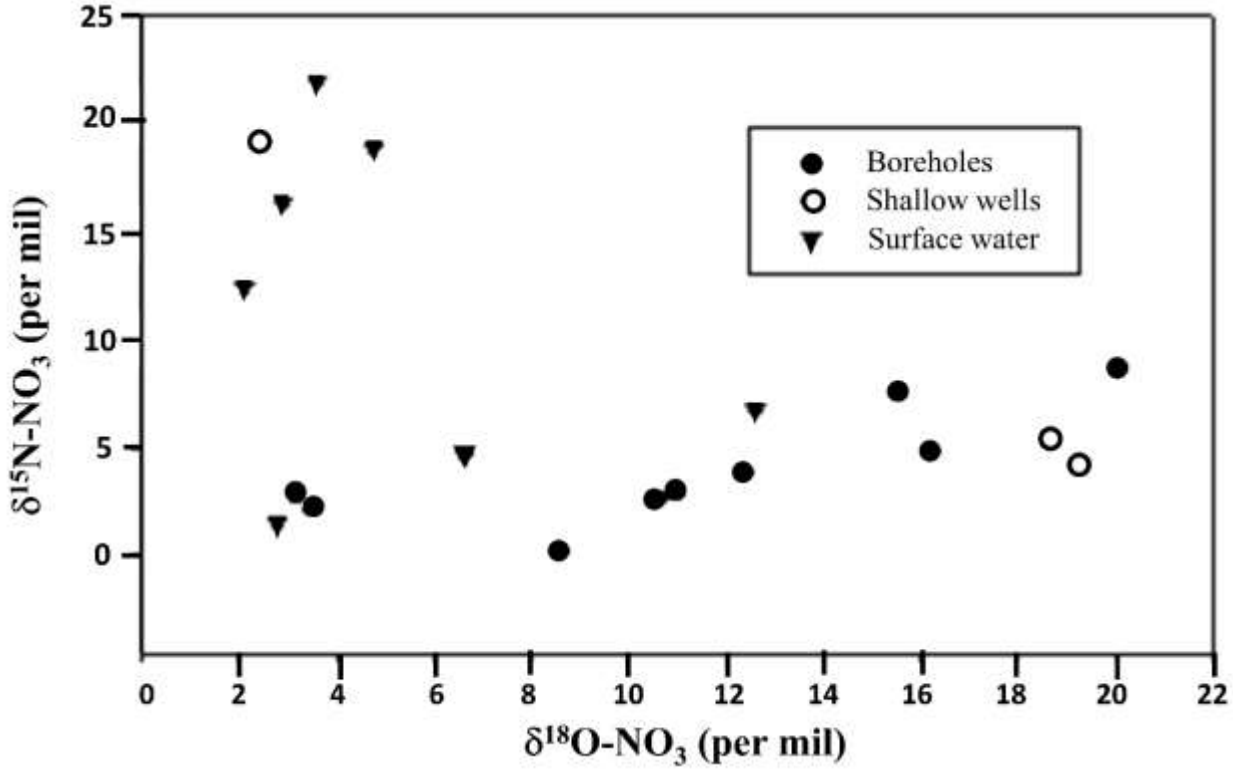

Figure 9: **δ^{15}N-nitrate values against δ^{18}O-nitrate values for both groundwater and surface water**

4.4 Land Use and Cover Change Vs. Nitrate Enrichment

The presence of nitrate and other nutrients at high levels in natural waters usually indicates that there is anthropogenic influence on the water quality (Salvado *et al.*, 2006). In the studied area, agriculture is a major economic activity followed by animal keeping but also use of pit latrines is common in some households. The management of wastewater in Babati town is depending on on-site sanitation system. There is no proper treatment for faecal sludge in Babati town. The forms of disposing which exist in Babati town include burying the sludge at nearby hole, abandoning it or disposing it in an open area about 5 km from the centre of the town area. These may have contributed to the pollution risk on water resources in the area because of the possibility of pollutants being released from both point and nonpoint sources. Elevated levels of nitrate were detected in some boreholes and shallow wells located in highly populated areas where use of pit latrines, application of fertilizer and animal husbandry were commonly practiced. Similar cases of groundwater pollution with high levels of nitrate have been reported in Babati and other parts of Tanzania (Elisante & Muzuka, 2017; Nkotagu, 1996; Pantaleo *et al.*, 2018a). The sampling point BH3 with a nitrate concentration of 54.5 mg/L and δ^{15}N-nitrate of 3.5 ‰ was located in a lowland area surrounded by maize farms where nitrogenous fertilizers were highly applied. This implies that the nitrate may be originated from anthropogenic activities such as application inorganic fertilizers in farms. However, water samples from the Lake Babati revealed low levels of nitrate.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Generally, for the present study, the analyzed ground and surface water samples revealed relatively low levels of nitrate and trace elements. Five groundwater samples had nitrate concentration higher than the background levels and one sample exceed the WHO maximum concentration recommended for drinking water of 50 mg/L. Such high nitrate levels may be associated with human activities such as application of synthetic fertilizers and animal manure in farms around the study area. Chemical composition of ground and surface water from the study area is largely influenced by the aquifer lithology than anthropogenic activities. Interpretation of hydro-chemical results showed that calcium carbonate dissolution and ion exchange processes controls the major cations chemistry of Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+} as well as the anionic chemistry of HCO_3^-, Cl^-, NO_3^- and SO_4^{2-}.

The present study has observed land use change in the study area whereby huge proportion of the land has been converted into human settlement and agricultural lands due to rapid urbanization and population growth. Farming activities and animal husbandry seem to be a lead cause in nitrate enrichment in ground and surface water of Babati town whereby enriched values of $\delta\ ^{15}N$-nitrate were mostly found at points close to the agricultural fields and in areas characterized by livestock keeping.

5.2 Recommendations

The study recommends protection of surface and groundwater quality through preventing anthropogenic activities around the water sources. Also, further study on the origin of surface and groundwater in the aquifers around the study area is required so as to recognize their pathways before the surface and groundwater quality protection measures to be taken

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RESEARCH OUTPUTS

(i) Publication

Mallya, C. L., & Rwiza, M. J. (2021). Influence of land use change on nitrate sources and pollutant enrichment in surface and groundwater of a growing urban area in Tanzania. *Environmental Earth Sciences, 80*(3), 1-14.

(ii) Poster Presentation