SCHOOL OF ENVIRONMENTAL SCIENCES

DEPARTMENT OF ECOLOGY AND RESOURCE MANAGEMENT

Remote Sensing of Harmful Algal Blooms (HABs) in water bodies of Vhembe district area, Limpopo province, South Africa.

By

LINTON FHATUWANI MUNYAI

STUDENT NO: 11620878

SUPERVISOR: Prof J.R Gumbo

CO-SUPERVISOR: Mr F Dondofema

A thesis submitted to the Department of Ecology and Resource Management in the School of Environmental Sciences, University of Venda in partial fulfilment of the requirements for degree of **Master of Environmental Sciences (MENVSC).**

July 2019

Table of Contents

Abstract

Satellite remote sensing techniques have been proved to be the best methods for quantifying chlorophyll-*a* levels by estimating algal concentrations in water bodies. Harmful algal blooms (HABs) are posing a significant threat to the many water bodies in South Africa. This study aims at developing remote sensing solution to estimate chlorophyll concentrations in water bodies of Vhembe district municipality using recently launched Landsat 8 OLI. It is the first study to provide quantitative water quality information for the Vhembe region's water bodies from a time series of satellite remotely sensed data and in-situ laboratory data. The objectives of this study was to evaluate spatial and temporal distributions of algae in water bodies and fish-ponds, to assess water quality parameters, namely: chlorophyll-*a* and turbidity and to compare data obtained from satellite remote sensors with *in situ* data. The 30 meters spatial resolution multispectral Landsat 8 OLI for 2016, 2017 and 2018 were used to derive chlorophyll-*a* estimate from an existing model at three water bodies. The chlorophyll-*a* concentrations measured during in-situ were employed to validate the Landsat derived chlorophyll-*a* estimates. The results from this study shows that Landsat derived chlorophyll-*a* estimates are correlating with field measurements. In all the reservoir, it was detected that there is low content of harmful algal blooms and thus the water bodies are in good condition since the chlorophyll-*a* concentrations were very low (ranging from 0 to 0.6 $mg.m^{-3}$). In conclusion, it can be stated that Landsat 8 OLI sensor has the potential to map inland water bodies dominated with algal blooms at certain extent. It can further be stated that Landsat 8 OLI is suitable for monitoring the growth of HABs in aquatic ecosystem and is cost effective. This study also evaluated the potential of Banana peels powder and K_2SO_4 to inhibits the growth of algae (batch experiment). The water samples were collected at Tshifulanani and Lwamondo fish ponds where there are floating algae. The samples were collected seasonally and analysed for pH, water temperature, Total Dissolved Solids, Electrical conductivity, Dissolved Oxygen, turbidity, chlorophyll-*a* and absorbance. From the laboratory experiments, there was a variation in the values of absorbance (0.936A-1.234A), PH (7.1-8.3), EC (63.1- 87.9 µs/cm), TDS (52.6-69.7mg/L), water temperature (25.5-29.3°C) and Dissolved oxygen (5.3-7.1mg/L). The concentration of chlorophyll-*a* for Tshifulanani and Lwamondo fish ponds ranges were (2.14-15.96 mg/m^{-3}) and (0.65-15.66 mg/m^{-3}) respectively. A batch experiment was conducted to determine the potential of banana peels powder on inhibition of algal blooms in water samples by measuring absorbance at 750nm. It can be concluded in this study that banana peels have a potential to inhibits the growth of algae in fish ponds. The Absorbance has shown a rapid decrease from 0.936A to Zero from day 1 to day 7 respectively. The inhibition of cyanobacteria by banana peels is followed using Potassium sulphate in treating the algal blooms in water samples. Both banana peels and potassium Sulphate has shown a positive response in treatment of algae on the batch experiment. The results of this study revealed that high concentration of physico-chemical parameters promote the growth of cyanobacteria in fish ponds but does not have negative effects on the fish except the oxygen competition with algal blooms. The statistical analysis in correlating the chl-a field measurements and remotely sensed data showed a positive outcome where K values were very high from 70% to 89%. These results show high level of agreement of correlation values of field chlorophyll-a concentration and satellite remotely sensed variables.

Keywords: *Chlorophyll-a, Harmful Algal blooms, Water quality, Banana Peels.*

DECLARATION

I **……………………………………………………………………….** hereby declares that this dissertation for the degree of Master of Environmental Sciences at the University of Venda, hereby submitted by me, has not been previously submitted for a degree at this university or any other university, that it is my own work in design and execution and that all reference material contained therein has been duly acknowledged.

Signature………………………… Date……………………………….

DEDICATION

This thesis is dedicated to my family. A special feeling of gratitude to my Mother, Tendani Mulaudzi Munyai for the love and words of encouragement throughout the entire study period. My sisters: Nganea and Onndinda, My young brother Adivhaho Duncan and my love Ponisile Mboweni. Special dedication to the late Mr Gilbert Nyathela who never left my side and always being courageous.

ACKNOWLEDGEMENTS

I wish to express my gratitude to my supervisor, Prof Jabulani Gumbo. This thesis would not have been complete without his expert contributions, financial support and patience. I am also most grateful for his faith in this study.

I would also like to express my special thanks to my Co-supervisor Mr Farai Dondofema for providing me with technical skill and input on the study.

A special thanks to Dr Kawawa Banda from Zambia, if you were not there, I don't know what would have happened with Remote Sensing concept on this thesis.

I thank the Univen Aquaculture Research group and the Department of Ecology and Resources Management together with the Department of Hydrology and Water Resources for allowing me to use both of their laboratories for analysis. I also extend my appreciation to Dr Sam Kaheru for providing me with a working space for conducting experiments in the School of Education, Physical Science Laboratory, University of Venda, he was so kind.

I would also like to thank NRF (National Research Foundation), NRF/DAFF project UID 98686, "Cyanobacteria and their cyanotoxins Impact on Inland Aquaculture" for funding this Project.

Lastly, I wish to acknowledge all who shared their knowledge on this research work, and everyone not mentioned here who contributed on this thesis, I say thank you very much

List of abbreviations/Acronyms

Chl	Chlorophyll
DAFF	Department of Agriculture, Forestry and Fisheries
DWAF	Department of Water affairs and Forestry
DO	Dissolved Oxygen
EC	Electrical Conductivity
HABs	Harmful Algal Blooms
MERIS	Medium-Resolution Imaging Spectrometer
MODIS	Moderate-Resolution Imagine Spectrometer
MPH	Maximum Height Peak
SPOT	Satellite pour l'Observation de la Terre
TDS	Total Dissolved Solids
USEPA	United State Environmental Protection Agency
XRF	X-ray fluorescence

List of Tables

List of Figures

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Anthropogenic activities severely deteriorate the water quality of many streams, rivers and dams. Anthropogenic activities progressively subject the surface water bodies to stress, and this significantly decreases the quality of the water for aquatic life (Rashid and Romshoo, 2013). Most of the freshwater resources are threatened by eutrophication and this are increasing in severity within developing countries (Vilmi et al., 2015). On this phenomenon of water quality deterioration by eutrophication which leads to the increase of cyanobacterial species of harmful algal blooms (termed red tides) in our freshwater resources, remote sensing has been used previously to monitor these phenomena (Winarso and Ishizaka, 2017). Remote sensing uses data sets and statistical regressions techniques to analyse reflectance from a water body. The reflected energy is captured by satellite sensor and can be acquired for analysis. Understanding aquatic ecosystem and threats to these ecosystems can reveal many challenges faced by different organisms in life.

Remote sensing provides useful information for the management of water resources both in marine and freshwater ecosystem. This study will be used for mapping cyanobacterial blooms in small fish ponds in within the Vhembe district. Cyanobacterial Blooms or Harmful Algal Blooms (HABs) are increasingly attracting the attention of water authorities, environmental agencies together with government departments since they are posing water quality and treatment problems (Kutser et al., 2006). These HABs are also threatening aquatic ecosystems and human health in Africa and globally due to its increasing accumulation in most of freshwater resources. According to (Tebbs et al., 2013), It has been shown that quantitative mapping of cyanobacteria during bloom conditions is possible with hyper-spectral instruments of remote sensing.

Fish kills have occurred for many years. Some of these deaths could be from cyanobacteria toxins which have been ingested by fish during feeding on floating diets or these toxins can also be passively assimilated through gills during breathing (Dawood et al., 2015). Most algae species are considered helpful in food-fish production ponds. They release oxygen as by-product of photosynthesis process and also remove toxic compounds from a water column such as ammonia and nitrates (Huang et al., 2018). Inland fisheries contribute to economic development, poverty alleviation and food security whereas on the other side they degrade the quality of water resources (McCafferty et al., 2012). Fish feeds are also part of substances which contributes to degradation of water quality in food-fish production ponds. The evidence suggest that eutrophic conditions lead to increasing dominance of HABs which pose threat to aquatic ecosystems through producing potentially lethal cyanotoxins (Paerl et al., 2016).

According to Trescott (2012), harmful algal blooms (HABs) in surface waters such as lakes and ponds results from the impacts of anthropogenic and natural activities. Nutrients loads in surface waters also contribute to the increased growth of HABs in our water bodies. It is important to monitor algal blooms in small fish ponds so as to provide knowledge, indicators of degraded water quality in different areas and for public alert on current situation of harmful algal blooms in our water resources (Adeleye et al., 2016).

Since water treatment is very expensive in most rural areas, there is a need for cost effective and environmentally friendly measures that can be undertaken to remove algae in the water (Lawton and Robertson, 1999). With the increase on the incidence of HABs occurrence in water supplies and water ponds containing fish, coupled with increase global population and climate change, it is of paramount importance that research studies focuses on alternatives treatment technologies to manage harmful algal blooms (HABs) particularly in water bodies intended for drinking, livestock and aquaculture. Batch experiments have been used in the previous to treat cyanobacteria but none of them have come with a cost-effective treatment of algae in fish ponds. This study provides the most effective and innovative ways of inhibiting algal blooms in aquaculture ponds using banana peels and potassium sulphate during a batch experiment.

1.2 PROBLEM STATEMENT

There a few studies focusing on monitoring inland small-fish-dams harmful algal blooms (HABs) using remote sensing in the Limpopo Province, most studies are concentrated in coastal areas of South Africa (Matthews et al., 2010). Despite some studies conducted in South Africa, few of them looked at the remote sensing of cyanobacteria-dominant algal blooms in coastal areas of Cape Town (Matthews et al., 2010). However, this study also focuses on fish kills by Harmful Algal Blooms (HABs), in small water ponds together with monitoring the algal growth at these ponds.

There is limited surface freshwater in South Africa and this limited freshwater is subjected to environmental degradation, particularly from eutrophication (Matthews & Bernard, 2015).

Aquatic ecosystems are poisoned by cyanobacterial toxins which include HABs, posing threats to extinction of some aquatic animals. The condition of a water bodies (scum on top of lakes or a ponds) can be viewed well using satellite images. Therefore, it is important to for us to take measures of assessing, maintaining and protecting water quality through using advanced mechanisms and cost-effective treatment options of HABs.

1.3 Research Objectives

1.3.1 General Objective

- To evaluate the efficiency of remote sensors to assist in characterizing the presence, distribution, and concentration of Harmful Algal Blooms (HABs) in freshwater systems from multiple approaches which includes; visual interpretation, spectral analysis and *in situ* validation and their treatment options.

1.3.2 Specific Objectives

- To determine spatial and temporal distribution of algae in small-fish-ponds of Vhembe district region using satellite capabilities.
- To discover possible solutions that can reduce harmful algal blooms (HABs) in small fish ponds.
- To assess physicochemical parameters in fish ponds and in the batch water treatment, namely: chlorophyll-*a*, turbidity, PH, Water temperature, Dissolved oxygen, Total Dissolved solids and Electrical Conductivity.

1.4 Justification of the study

Despite many studies done on the satellite remote sensing of harmful algal blooms (HABs) or cyanobacterial blooms in South African coastal areas and worldwide (Matthews & Bernard, 2010, 2015; Trescott, 2012; Shen et al., 2012), there is need to research more about aquatic conservation. This research helps on the conservation of aquatic ecosystems and addressing the problem of water quality. Harmful algal blooms (HABs) are deleterious phenomena and are rapidly accumulating in most aquatic systems (Shen et al., 2012), hence there is need for an urgent response from researchers.

Water quality challenges have become a topical issue locally and globally, thus there is need to establish more approaches to deal with water quality problem. The South African government's aim is to supply portable water as basic resource to every human being as stipulated in government regulations and policies (Water Service Act) Act No 108 of 1997. This shows that it is important to study water quality on our freshwater resources to ensure that there is quality water for national consumption.

Matthews & Bernard (2015) note that there are many water supply bodies that are negatively affected by cyanobacterial blooms and this is an issue of serious concern for water security and supply in South Africa. These challenges can be monitored by satellite remote sensing devices mounted on space (Mathews et al., 2010) and treatment options should be put in place to manage the growth of cyanobacteria in water bodies particularly fish ponds. There is no short-term monitoring of cyanobacterial blooms in water bodies of Vhembe district using remote sensing. This study being the first, will provides significant approaches for government departments and other researchers who would like to do long term monitoring of water supply bodies in the Vhembe region, particularly for hydrological analysis on freshwater systems.

1.5 Delineation and Limitations

This project only focuses on the application of remote sensing data on the water bodies of Vhembe district area. It is restricted to inland freshwater aquaculture and possible monitoring of aquaculture using remote sensing for harmful algal blooms. Remote sensing data will further be integrated with *in situ* validation. It also identifies water bodies which are mostly dominated by harmful algal blooms (HABs) and possible mitigation measures of those HABs using batch experiment conducted in the laboratory. Most of the previous satellite data (satellite images) on the study area may hinder the researcher from further investigating the problem in the Vhembe region.

1.6 Underlying Assumptions

Harmful algal blooms (HABs) present an increasing threat to the health of freshwater ecosystems and to humans who use this water for drinking and other domestic uses.

1.7 Description of the study area

Vhembe district area is situated in Limpopo province, the northern province of South Africa (Figure 1.1). The area experiences cool, dry season temperatures during winter ranging from 4° to 20° C with warm, wet, summer temperatures ranging from 17° to 27 °C. The average annual rainfall is about 300 mm, with most of it falling in the summer months (Edokpayi et al., 2016). Climate (especially precipitation and mist precipitation) differs dramatically because of the extreme topographic diversity and elevational changes over short distances (Mostert et al., 2008). The land elevation at this area influences runoff patterns. The catchment area is dominated by sandy clay loam and is mostly used for small scale farming and conquered by commercial fruit farming and forestry (Odiyo et al., 2012).

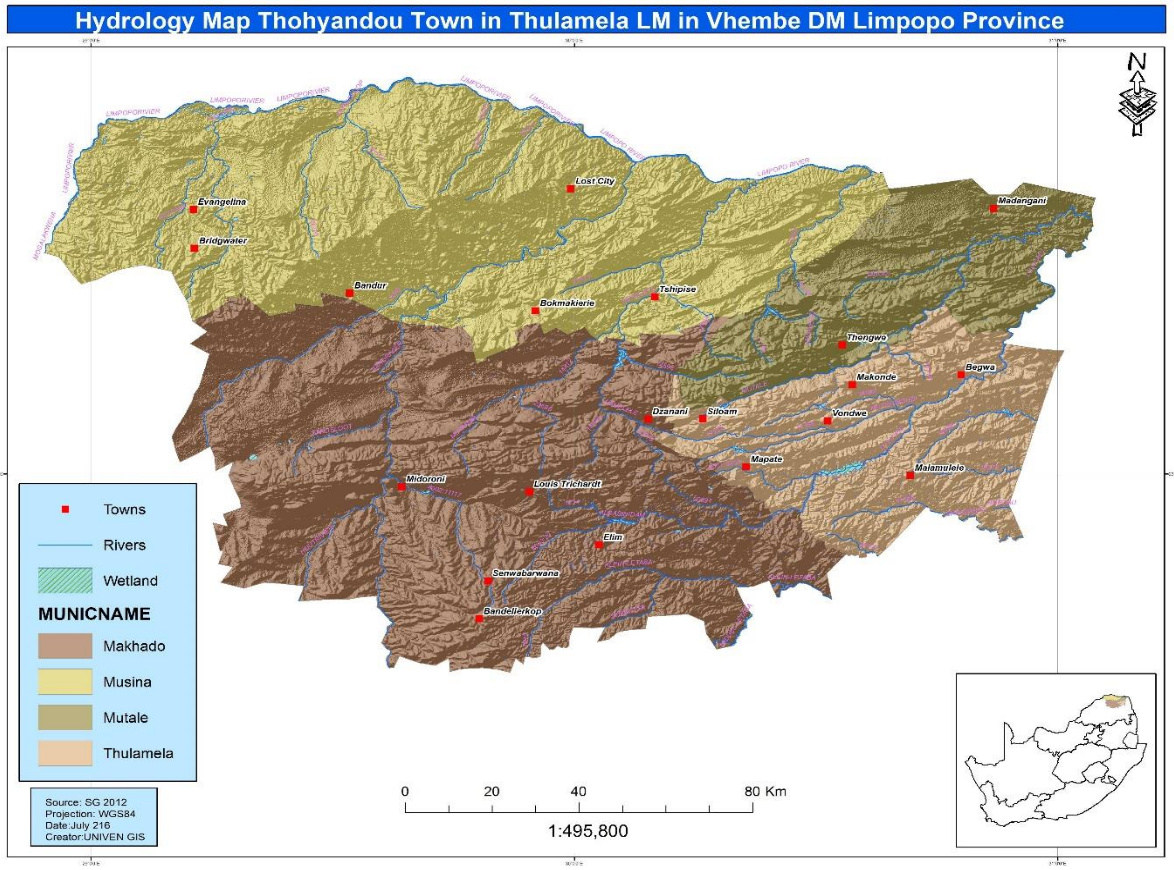

Figure 1. 1: Catchment map of Vhembe region in Limpopo province.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Harmful Algal Blooms (HABs) are increasingly threatening aquatic ecosystems, water quality, particularly inland aquaculture fish dams by producing harmful toxins and limiting sunlight penetration in the water. Furthermore, the presence of HABs in aquaculture fish dam's results in fish kills from suffocating since HABs reduces the amount of dissolved oxygen in water. HABs vastly grows under conditions such as, high temperature environment, in the presence of high content of phosphates and nitrates and less dissolved oxygen in water (United State Environmental Protection Agency (USEPA 2012). Remote sensing has been used worldwide to monitor the growth of Harmful Algal Blooms (HABs) in water bodies, however this study was intended to the use of satellites in monitoring the growth of algal blooms in inland aquaculture fish dams. This study reveals the effectiveness of remote sensing data to provide a clear distribution and identification of growth of algal blooms. Aquaculture practices contribute massively to national development and provide job opportunities for people in South Africa. The presence of cyanobacteria in fish dams generally affects fish production thus needs to be attended to with immediate effect.

Inland fisheries have highly contributed to socio-economic development, poverty alleviation and food security. In South Africa aquaculture practices contribute massively to national development and provide job opportunities for many people. However, some of the inland fisheries practices like use of fish feeds on fish pond also degrades the quality of water resources and reduce benefits that would have accrued from these resources (Tang et al., 2016). Evidence suggests that eutrophic conditions lead to increasing dominance of Harmful Algal Blooms (HABs) which pose threat to aquatic ecosystems through producing potentially lethal cyanotoxins in the water body (Koker et al., 2017). While most algae species are considered useful in food-fish production ponds where they not only release oxygen as a by-product of the photosynthesis process but also get rid of toxic compounds from water column such as ammonia and nitrates (Zimba et al., 2001), it has been recognized that HABs are increasingly threatening aquatic, water quality, particularly in inland aquaculture fish dams by producing harmful toxins and limiting sunlight penetration in the water. The ingestion of cyanobacteria toxin during feeding on floating diets or passively assimilated through gills during breathing contributes to fish kills (Dawood et al., 2015). Furthermore, the presence of HABs in aquaculture fish ponds result in fish kills from suffocating since HABs reduces the amount of dissolved oxygen in water.

Trescott (2012) observes that HABs in surface water result from the impacts of anthropogenic and natural activities. Nutrients loads in surface water also contribute to the increased growth of HABs in water bodies. To provide knowledge, indicators of degraded water quality in different areas and for public alert on the current situation of HABs, Adeleye et al. (2016) point out that it is of paramount importance to monitor algal blooms in inland water surfaces especially in small fish ponds that has so far been not the focus of many studies. Remote sensing has been used worldwide to monitor HABs growth in large water bodies. Through satellite remote sensing we can obtain valuable information on the management of aquatic ecosystem. With the use of hyper-spectral gadgets of remote sensing it is now possible to carryout quantitative mapping of cyanobacteria during bloom conditions (Hunter et al., 2016). However, the use of remote sensing in monitoring the growth of HABs has rarely been applied on small fish ponds. The current study was intended to use satellites in monitoring the growth of alga blooms in inland aquaculture fish ponds. It was designed to reveal the effectiveness of remote sensing data in providing a clear distribution and identification of growth of alga blooms

This review paper focuses on analysis of different measures used in determination of chlorophyll-*a* which is the principal aspect of photosynthesis, furthermore, it is the major indicator of the presence of HABs in aquatic environment. Several studies have shown that cyanobacterial blooms contribute to loss of water quality in water bodies (Edokpayi *et al*., 2014; Winarso and Ishizaka, 2017). In South Africa some studies have shown that 18 out of 25 river catchments are dominated by the eutrophic condition which facilitates the growth of HABs (DWAF, 2003). The major types of recurring cyanobacterial blooms found in fish farming over the past few years include *Microcystis aeruginosa*, *Anabaena*, *Aphanizomenon and Gloeotrichia* which produce toxins such as microcystin that are responsible for numerous fish kills and death of other animals in many aquatic ecosystem area in Southern Africa (Schrader et al., 2016).

2.2 Harmful Algal Blooms, chlorophyll-*a* and Remote Sensing

Remote sensing has widely been used in monitoring cyanobacterial and algae in lakes, oceans and dams. However, few studies were done focusing on remote sensing monitoring cyanobacteria in inland aquaculture water bodies by extrapolating algae, phycocyanin and chlorophyll-*a* present. Satellite remote sensing application requires satellite sensors operating in visible near infrared sensor with high spatial/temporal resolution and high radiometric sensitivity (Giardino et al., 2014). According to Shen et al. (2012), it is clear that remote sensing of monitoring HABs requires knowledge, skills and comprehensive understanding of remote sensing mechanisms. Present studies suggests that monitoring of cyanobacterial blooms using remote sensing as a tool is more complicated (Le et al., 2013). However, satellite remote sensing of monitoring inland water bodies impacted with HABs is currently limited to larger water bodies/lakes and handheld sensors because there are no satellite sensors with high spatial resolution to map inland water bodies since they are small (Kutser, 2009).

Many studies focused on chlorophyll-*a* estimation in turbid water using different algorithms, models and laboratory analysis of chlorophyll-*a* concentration (Hansen et al., 2013; Hansen et al., 2015; Le et al., 2013). Several studies on detection and monitoring chlorophyll-*a* in water bodies are based on the empirical models of reflectance, radiance in narrow bands and chlorophyll-*a* (Devi et al., 2015). Researchers collects field data on chlorophyll detection on through handheld satellite or sensors mounted on space to validate their models. This is a very good approach since satellites remote sensing data is calibrated or validated by field observation and ground truthing. Furthermore, the combination of all these methods makes the data more linked and as such, the results are reliable and conclusive.

2.3 Challenges to Aquaculture systems with Cyanobacteria

One of the main objectives of aquaculture systems especially in rural area is to provide food security and alleviate poverty by provision of employment to people. Numerous studies reported fish mortality in aquaculture systems from cyanobacterial toxins and oxygen competition (Zi et al., 2018). Most fish farming is vulnerable to deterioration of cyanobacteria and this is influenced by different environmental factors; physical, biological and chemical which are driven by anthropogenic activities. It is of paramount importance to reduce the impacts of cyanobacteria in fish farming hence this review intends to investigate the use of satellites and in-situ field data as a tool for monitoring the progression of HABs.

2.4 Remote sensing of Cyanobacterial Blooms and chlorophyll-*a* determination

Remote Sensing can be used to determine chlorophyll and cyanobacteria contents in deep and shallow waters. The concentration of chlorophyll-*a* content in water bodies has been determined using the empirical correlation between radiance and reflectance of algae in water bodies, thus few studies focused on narrow bands (Devi et al., 2015). Other studies developed models focusing on both empirical and semi-analytical algorithms for conducting in-situ spectral analysis (Mouw et al., 2015).

Most of the field data which are collected in remote sensing study are intended to validate models formulated, however some of the data is used to correlate the two sets of data (Satellite and in-situ data). It has been found that in-situ field measurements provide the water bodies spectrum and chlorophyll-*a* concentration through collection of water samples and analysing spectral reflectance from spectro-radiometer. Several work has been done in determination of chlorophyll and its derivatives with exceptions of pheophytin and phycocyanin in natural water systems by extracting the pigment from the plant material or the algal bloom (Milenković et al., 2012). Moreover, lot of methodology in determination of chlorophyll has been identified by researchers including the use of satellite remote sensing in extracting the green pigment found on algae by estimating chlorophyll content.

In detecting trophic status of chlorophyll-*a*, mathematical algorithms has been used with the application of top-atmosphere data from satellite especially MERIS. Matthews et al. (2012) used Maximum Height Peak (MPH) algorithm to detect cyanobacterial blooms, surface scums and chlorophyll-*a* by calculating the height of the dominant peak across the MERIS bands which are red and near infrared between 664 and 885nm wavelength. For chl-*a* estimation, two experimental-setup were conducted, this include MERIS and in-situ data to create more comparison model and to generate reliable model which can be best fitted. The idea of using both MERIS and in situ data was to allow models to cover a wide trophic waters dominated by surface scums, where oligotrophic, hypertrophic and dry floating algae are differentiated based on the MPH variable magnitude Matthews et al. (2012).

2.5 Historical application of satellite remote sensing in detecting and monitoring harmful algal blooms

During the past decades several satellite remote sensing devices have been used for measuring harmful algae propagation and distribution at varying degrees of spatial, spectral and temporal resolution (Trescott, 2012). Empirical satellite models have played a significant role in the detection of HABs based on the spectral characteristics of green pigments found in aquatic ecosystems. As Stumpf et al., (2016), Meler et al. (2017) and Raber *et al.* (2007) observe, chlorophyll-*a* has two absorbance peaks near 433 nm (blue) and 686 nm (red), a maximum reflectance near 550nm (green) and a reflectance peak around 690-700nm present in the visible portion of the electromagnetic spectrum. Cristina et al. (2016) explain that the concentrations of chlorophyll-*a* can be estimated using satellite bio-optical algorithms based on the amount of light reflected or absorbed at specific wavelengths (λ) in the visible spectrum. Studies have shown that bio-optical algorithms that have been established by a number of researchers, tested, compared and proven using various in-situ measurements and refined computational measurements have resulted in the attainment of accurate and valid results (Trescott, 2012). Various approaches have been developed, examples include common approaches such as the empirical and semi-analytical techniques for developing bio-optical satellite algorithms over Case II water. Further, more sophisticated techniques that provide more accurate alga detection are also available such as the Neural Networks Model. This technique has been used for satellite water quality modelling and has now become popular for modelling marine and inland waters (Trescott, 2012). However, this technique is very complex and require a lot of time and large amounts of training data for better performance. But Camps-Valla et al. (2006) came up with two analytical methods, Support Vector Machines (SVMs) and Relevance Vector Machines (RVMs) that have been proven effective with smaller training data sets than those required for neural networks.

Satellite sensors that have been utilized for hydrologic applications in monitoring HABs include some of the following: Landsat1-7, MODIS, MERIS, IKONOS, and SPOT (Table 2.1).

Table 2. 1: Previous and current operating satellite sensors for monitoring harmful algal blooms (HABs)

Satellite sensors			Launch date	End date	Resolution		
					Spectral bands & range	Spatial	Temporal
Landsat	1	**Multispectral Scanner (MSS)**	July 1972	January 1978	**4 Multispectral bands:** 1) 500-600 nm; 2) 600-700 nm; 3) 700-800 nm; 4) 800-1,100 nm	68 x 83 m for all MSS bands	18 days
	2	**Multispectral Scanner (MSS)**	January 1975	February 1982		68 x 83 m for all MSS bands	18 days
	3	**Multispectral Scanner (MSS)**	March 1978	March 1983	**4 Multispectral bands:** 1) 500-600 nm; 2) 600-700 nm; 3) 700-800 nm; 4) 800-1,100 nm. **1 Thermal band:** 10,410-12,350 nm	68 x 83 m for all MSS bands	18 days
	4	**Thematic Mapper (TM)**	July 1982	June 2001	**6 Multispectral bands:** 1) 450-520 nm; 2) 520-600 nm; 3) 630-690 nm; 4) 760-900 nm; 5) 1,550-1,750 nm; 6) 2,080-2,350 nm **1 Thermal band:** 10,400-12,500 nm	30 m for multispectral; 120 m for thermal	16 days
	5	**Thematic Mapper (TM)**	March 1984	Currently Operational		30 m for multispectral; 120 m for thermal	16 days
	7	**Enhanced Thematic Mapper Plus (ETM+)**	April 1999	Currently Operational	**6 Multispectral bands:** 1) 450-515 nm; 2) 525-605 nm; 3) 630-690 nm; 4) 750-900 nm; 5) 1,550-1,750 nm; 6) 2,090-2,350 nm **1 Thermal band:** 10,400-12,50	30 m for multispectral; 120 m for thermal; 15 m for panchromatic	16 days
	8	**Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)**	February 2013	Currently Operational	**11 spectral bands** **1)** Coastal aerosol. 2)Blue. 3)Green. 4)Red. 5) NIR 6) Swir-1. 7)Swir-2. 8) Panchromatic. 9) Cirrus. 10) Thermal Infrared-1. 11) Thermal Infrared-2	30m for multispectral; 15m for panchromatic; 30m for Thermal Infrared	16 days
	1		February 1986	December 1990	**3 Multispectral bands:** 1) 500-590 nm; 2) 610-680; 3) 780-890 nm **1 Panchromatic band:** 500 - 730 nm	20 m for multispectral; 10m for panchromatic	26 days
	2		January 1990	July 2009		20 m for multispectral; 10m for panchromatic	26 days

SPOT	3	September 1993	July 1997		20 m for multispectral; 10m for panchromatic	26 days
	4	March, 1998	**Currently Operational**	**4 Multispectral bands:** 1) 500-590 nm; 2) 610-680; 3) 790-890 nm; 4) 1,580-1,750 nm **1 Panchromatic band:** 610-680 nm	20 m for multispectral; 10m for panchromatic	26 days
	5	May 2002	**Currently Operational**		10 m multispectral; 2.5 m for Panchromatic	26 days
Rapid-eye		August 2008	**Currently Operational**	**5 Multispectral bands:** 1) Blue (440-510 nm); 2) Green (520-590 nm); 3) Red (630-690 nm); 4) Red-Edge (690-730 nm); 5) Near-Infrared (760-880 nm**)**	5m multispectral	1 day
Sea WiFS		August 1997	**Currently Operational**	**8 Multispectral bands:** 1) 402-422 nm; 2) 433-453 nm; 3) 480-500 nm; 4) 500-520 nm; 5) 545-565 nm; 6) 660-680 nm; 7) 745-785 nm; 8) 845-885 nm	1.1 km for all bands	1 - 2 days
MODIS	**Terra**	December 1999	**Currently Operational**	**36 Multispectral bands:** 1) 620-670 nm; 2) 841-876 nm; 3) 459-479 nm; 4) 545-565 nm; 5) 1,230-1,250 nm; 6) 1,628-1,652 nm; 7) 2,105-2,155 nm; 8) 405-420 nm; 9) 438-448 nm; 10) 483-493 nm; 11) 526-536 nm; 12) 546-556 nm; 13) 662-672 nm; 14) 673-683 nm; 15) 743-753 nm; 16) 862-877 nm; Bands 17-36) 890 - 14,385 nm	250 m for bands 1 & 2; 500 m for bands 3 - 7; 1000 m for bands 8 - 36	1 - 2 days
	Aqua	May 2002	**Currently Operational**		250 m for bands 1 & 2; 500 m for bands 3 - 7; 1000 m for bands 8- 36	1 - 2 days

MERIS	March 2002	**Currently Operational**	**15 Multispectral bands:** 1) 407.5-417.5 nm; 2) 437.5-447.5 nm; 3) 485-495 nm; 4) 505-515 nm; 5) 555-565 nm; 6) 615-625 nm; 7) 660-670 nm; 8) 677.5-685 nm; Bands 9-15) 700-905	From 300 -1,200 m	3 days
IKONOS	September 1999	**Currently Operational**	**4 Multispectral bands:** 1) 445-516 nm; 2) 506-595 nm; 3) 632-698 nm; 4) 757-853 nm **1 Panchromatic band:** 450-900 nm	4 m for multispectral; 1 m for panchromatic	< 3 days

Sources: (Hooker et al., 1992; McClain et al., 1992 & 1998; O'Reilly et al., 1998; Jensen, 2007; Raber, 2007; Rocchio, 2010)

2.6 Contribution of aquaculture to economic growth and development

Globally aquaculture industry is growing faster than any other food production sector. This is because there has been a tremendous increase in the consumption of farmed fish in the globe, including South Africa (DAFF, 2012; FAO, 2014). Aquaculture in South Africa is marketed both locally and internationally and is currently doing well due to increase in the international demand of aquaculture species such as abalone. Fresh water aquaculture has the potential to spur economic growth and development and to improve food security in both rural and urban areas of South Africa. By 2012 up to 1607people were permanently employed in the aquaculture industry, an increase of 3% in comparison to 2011 (DAFF, 2012). This is an achievement that is in line with the South African National Development Plan (NDP) of creating job opportunities for citizens. It has also been recognized that the sector mainly (81%) employ Historically Disadvantaged Individuals (HDI). In recognition of this the National Department of Agriculture, Water Affairs and Forestry came up with policies aimed at supporting aquaculture development in the country. Aquaculture in South Africa is divided into two, the freshwater and marine aquaculture. Freshwater aquaculture consists mainly of the following species: Brown trout, rainbow trout, African cat fish, Mozambique and Nile tilapia, marron, waterblommetjies, ornamental fish and crocodiles (DAFF, 2012). While the marine species mainly consists of: White pawns, Atlantic Salmon, oysters, clownfish, West and East coast rock lobster, Spanish and brown mussels, yellow tail, Dusky and Silver Kob, White Margined Sole, Blood Worm, Scallop and sea weeds. Freshwater species are mainly farmed in recirculating systems, earth ponds or raceways (DAFF, 2012). However, HABs are threatening the flourishing aquaculture production especially in fish ponds and thereby posing a threat to the thriving industry in South Africa.

2.7 Burdens of Harmful Algal Blooms (HABs)

HABs pose a threat to water quality and to aquatic life in a number of ways, first by depleting oxygen during decomposition process, secondly by releasing toxins and third by reducing the penetration of sunlight into the water (Hansen *et al.*, 2015). The harmful nature of these HABs from an environmental context starts with reducing clarity in water, thus suppressing aquatic macrophytes which in turn affect invertebrates and fish habitat negatively. On the other hand decomposition of dying bloom leads to the depletion of oxygen leading to the death of fish (Paerl & Otten, 2013). And finally, the HABs produce toxins which can cause life threatening acute intoxication thus in mammals including human beings thus affecting the endocrine and the digestive system (Carmichael and Boyer, 2016).

One of the common types of HABs in freshwater and saltwater is the Cyanobacteria (also known as blue-green algae). They produce cyanotoxins which poses numerous health hazards to animals and humans (Carmichael and Boyer, 2016). For example, in February 1996, sixty people were poisoned in Brazil as a result of drinking water containing microcystin, a toxin produced by the Microcystis cyanobacteria species (Pouria *et al*., 1998). In South Africa two species of the HABS, eutrophication and cyanobacteria have imposed big economic burden because of not only the large amount of costs incurred in the treatment of water, but also the negative effects on water-side property, losses in tourism and recreation as a result of people's negative perception of water quality, negative human health impacts from poor water quality leading to infectious diseases, animal mortalities, poor aquatic ecosystem leading to reduced biodiversity and proliferation of invasive species and high cost of managing and controlling aquatic macrophytes (e.g. hyacinth weed) (Mathews and Bernard, 2015).

2.8 Aquaculture in South Africa

South Africa has been known to produce farmed fish such as Tilapia, Mussel, Oysterwhich and Abalone which are mainly farmed in the coastal areas of South Africa in Western Province (DAFF, 2011). This is the first leading province in fish farming, followed by the province of Mpumalanga, KwaZulu Natal, Eastern Cape, Limpopo, Northern Cape and North West with 43.8%, 12.5%, 12.5%, 12.5%, 3.1%, 3.1% and 1.6% respectively (Botes et al., 2006). The aquaculture industry has rapidly increase from year 2000 to 2009 from 33% to 56% with increase in production of tilapia and catfish which are abundant in province like Limpopo and Mpumalanga (DAFF, 2011. The industry has also increased the employment rate in all provinces where fish farming are being practiced while also contributing to economic growth and sustainability.

The development of aquaculture in South Africa for food production was started in 1980 in rural areas of South Africa. Species such as Tilapia, Silver carp, Bighead carp, Catfish, Ornamental, salmonids and Grass carp were farmed in various areas, including former homelands of Venda, Transkei, Lebowa and Gazankulu (Rouhani and Brits, 2004) between 5 to 10 tonnes of fish per year. The production of warm water species such as ornamental fish decreases in winter because the temperature becomes very cold for fish and also salmonids (cold water fishes) production decreases during summer because it becomes too warm in the summer (Pretorius et al., 2016).

In the Western Cape fish production decreases every year in winter due to water availability and the low temperatures. In 2002 some farms were closed in the Western Cape due to algal problems, which were causing an unpleasant taste to the fish (Berold. 2005). The North-West Province, lowveld areas of Limpopo and Mpumalanga Province, low-lying areas of Kwazulu-Natal and lower Orange River in Northern Province have suitable temperature conditions for the culture of warm water fish species such as Tilapia, Ornamental fish, Barbel and Carp, whereas Trout culture can be farmed in the Western Cape and Mpumalanga in the Lydenburg area (Rouhani and Brits, 2004).

Aquaculture is now able to employ unskilled employees and skilled employees. For unskilled employees, training in aquaculture is offered. The Employment rate increased in 2011 at 2% and the majority of people employed in 2011 were males at 74% and females 23% (DAFF, 2012). The Western Cape had the highest fish production level in 2011, followed by the Eastern Cape, Northern Cape and Kwazulu-Natal. DAFF reported that in 2030 fish supplies will dominate fish production because the world population is increasing, which will lead to a higher demand for fish (DAFF, 2013). About 12.5 % of the freshwater fish produced is being exported to Asia, Europe and America (Botes, et al., 2006). South Africa uses different methods of fish farming, such as tanks, cages, recirculation, earth ponds and trays ponds. However, tanks are commonly used because they are cheap (Botes et al., 2006).

2.9 Cyanobacteria and aquaculture systems

Most of the fish farming system are usually disturbed by the presence of cyanobacterial blooms, normally floating or suspended in water. This poses a serious problem to the fish because they start competing for oxygen and light while cyanobacteria use more oxygen in water resulting in fish mortality. Other ponds managers have used different methods to kill cyanobacteria in fish ponds, however the results might be positive with detrimental effects either on fish or water.

2.10 Treatment of Cyanobacteria in water

Managers have used copper sulphate $CuSO_{4,}$ sodium carbonate peroxyhyrate, aluminium sulphate, copper chelate compounds and biological control methods using bacteria and viruses to manage cyanobacteria in water (Fan et al., 2013; WQRA, 2009; Fan et al., 2014). Biological treatment of cyanobacteria has been considered a better method because its application in water does not have negative effects on the aquatic environments (Fan et al., 2014).

2.11 Conclusion

The literature review showed that several studies have investigated the potential of satellites remote sensing techniques in determining the concentration of chlorophyll in water bodies. Studies further looked on the treatment of Harmful Algal Blooms (HABs) in aquaculture and water bodies using different mechanisms such as mechanical, chemical and biological control of cyanobacteria in water. The remote sensing technique has been the most useful mechanism to deduce the occurrence of cyanobacteria in water bodies and to study their distribution with relation to temporal characteristics. Certain methods for treatment of cyanobacteria have been considered working, however they are not cost-effective and are time consuming. The current study is intended to investigate the low-cost traditional methods of using banana peels to treat cyanobacteria in water and not affecting the water quality.

CHAPTER THREE: METHODOLOGY

3.1 Introduction

This chapter outline the methods used during experiments to achieve all objective that are presented in chapter one. It includes the physicochemical quality of water from the aquaculture ponds and water in the beakers during experiments. The physicochemical conditions measured in the field and in the laboratory were PH, water temperature, Electrical conductivity (EC), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Chlorophyll-*a* and Turbidity. Keremah et al. (2014) alluded that water used for fish farming should be of the best quality to give the best production in the aquaculture industry.

3.2 MATERIALS AND METHODS

3.2.1 Site Selection of sampling

Fishponds were identified in the Thulamela municipality. We found that the fishponds identified were functioning well and had water in them. The area of Fishpond A and B was measured and was found to be 12.57m^2 and 120m^2 respectively. Floating algae was observed on those fishponds monitoring of algal blooms on those fishponds were difficult because the ponds are deep, and no measures were taken to control the growth of algae on the ponds. Water samples were collected from Lwamondo (Tshifulanani) and Lwamondo murahu Ha-thavha fishponds (Figure 3.1).

Figure 3. 1: A and B Showing the Tshifulanani(A) and Lwamondo(B) fish ponds

3.2.2 Sampling tools used

250ml sterilized glass containers were used during the collection of samples. Permanent marker was used to label the samples accordingly to avoid mixing the samples during transportation. A GPS was also used to record the coordinates of where samples were collected, and this was going to assist in georeferencing the sampling points of the study area.

3.2.3 Sample collection

Water samples containing algal suspension were collected from the fish pond with 250ml glass containers. A minimum of 3 samples were collected in each aquaculture pond for physico-chemical analysis.

3.3 SAMPLE ANALYSIS

3.3.1 Analysis of Physicochemical parameters in water samples

Algal blooms together with fish can be able to survive in a certain condition and immediately the condition becomes unfavourable, the fish can no longer survive. There are minimum concentrations of pH, TDS, EC and Water temperature where fish can have optimal growth and production. Therefore, it was very important to determine the concentration of PH, TDS, EC, DO, Turbidity and water temperature in order to find out if the environment is suitable for the survival of fish and growth of algae. Physico-chemical parameters were analysed using ACCSEN potable GLP Multimeter, PC70 calibrated as per manufacturer instructions. Turbidity was analysed using Lovibond Turbidity meter (TB 250 WL) while Dissolved Oxygen was determined using the BANTE 821 Potable Dissolved Oxygen Meter.

3.3.2 Chlorophyll-*a* analysis

Water samples were defrosted, homogenised in an electric homogeniser and filtered through a Whatman GF/F 0.7µm glass fibre filter papers, and the volume of the filtered samples was recorded. A 90% ethanol solution was used to extract the chlorophyll-*a* and concentration in mg/m^3 were measures using the spectrophotometric method and converted to µg/L. Absorbance was measured at 665 and 750 nm using a spectrophotometer (Orion aquamate 700, VIS spectrometer).

Water samples that were collected during summer and winter were analysed in the laboratory for Chl-*a* concentration. Chlorophyll-*a* calculation was performed by subtracting absorbance 665a-750a = corrected 665a absorbance 665b-750b = corrected 665b absorbance. The below equation 1 was used to calculate the concentration of chlorophyll in water samples:

$$Chl - a = \frac{29.62\ (665a - 665b) \times Ve}{Ve \times l} \qquad \text{...(1)}$$

Where: Ve = Volume of ethanol extract (ml)

Vs = Volume of water sample filtered (litres)

l = Path length of cuvette (cm)

3.3.3 Determination of inhibition and growth of cyanobacteria in the water samples.

To determine the inhibition and growth effect of cyanobacteria, absorbance was recorded at 750nm for banana peels treatment, Potassium treatment and control samples using the spectrophotometer (Orion aquamate 700, VIS spectrometer). The growth of cyanobacteria was observed by the rise in the values of absorbance readings and the inhibition was observed by the decrease in the values of absorbance at the specified wavelength. The procedure and results are well presented in chapter 4.

3.4 Remote Sensing and In-Situ Field Measurements

3.4.1 Sites for data collections

Three water bodies, namely; Nandoni, Albasini and Vondo dams in Vhembe District Municipality were considered for In-situ sampling of chlorophyll-*a* analysis using both Laboratory and Remotely sensed methods. Two dams (Nandoni and Vondo) are located under Thulamela Municipality and Albasini dam is located under Makhado municipality. All these dams are the water suppliers of almost all communities in Vhembe and they are distributed far from each other. Nandoni dam (Lat -22.983324° and Lon 30.579191°) is situated Ha-Budeli which is 30km from Thohoyandou town. The dam supplies water to different communities such as Thohoyandou, Sibasa, University of Venda and nearby communities. The reservoir has the total capacity of 164,000,000 cubic meters and a catchment area of 1380km^3 with the total surface area of 1570 hectares.

Vondo dam (Lat -22.946375° and Long 30.336539°) is situated at the mountainous area under Vondo Tribal authority. The reservoir is a source of water to communities such as Thathe Vondo village, Gondeni, Maranzhe and Phiphidi and has the total capacity of 30,000,000 cubic meters with 219 hectares of surface area. Whereas Albasini dam (Lat -23.107238° and Lon 30.117978°) is a source of water for communities such as Makhado town, Mpheni Village, Elim and Waterval. This reservoir has a total capacity of 25,200,000 cubic meters and a surface area of 350 hectares.

3.4.2 Measurements of Chlorophyll-*a* in the dams for comparison with Satellite data

Water samples for chl-a were collected randomly in each dam. The samples were collected along the water column at a range of 0.5-1 m in the morning at each site of the dam and stored on ice for analysis in the laboratory. 19 samples were collected from Nandoni dam and 8 Samples were collected from Vondo dam whereas 9 samples were collected from Albasini dam using a boat. The sampling sites were selected randomly along the dams and the concentration of chlorophyll-*a* was determined using the Spectro-photometrical method as described by Dalu et al. (2013).

3.4.3 Remote Sensing data acquisition and pre-processing

Three medium spatial resolution (30 m) multispectral Landsat 8 Operational Land Imager (OLI) images freely acquired over Nandoni, Vondo and Albasini for the year 2016, 2017 and

2018 were used to derive chlorophyll-*a* estimates from the selected points in the reservoirs (Table 3.1). On this study, all images with cloud cover greater that 75% were excluded to retrieve chlorophyll-*a* concentration accurately (Ndungu et al., 2013) The satellite images were acquired on the following dates:

Table 3. 1: Landsat acquisition information sourced from USGS ONLINE Archive (http://earthexplorer.usgs.gov/.

Satellites Images	**Date of Acquisitions**	**Landsat Scene ID**	
2016	August 26, 2016	LC81690762016223LGN01	**Path= 169** **Row= 76**
2017	August 26, 2017	LC81690762017241LGN00	
2018	August 26, 2018	LC81690762018228LGN01	

All Landsat images were downloaded from USGS and were in Digital number format (DN values). To derive chlorophyll-*a* from those images, the images were calibrated from DN values to Top-of-atmosphere spectral reflectance units (Wm^{-2} sr^{-1} μm^{-1}) using the algorithm provided by the USGS for converting reflective band to top-of-atmosphere reflectance (Equation 2). The algorithm is as follows:

$$\rho\lambda = M\rho Qcal + A\rho \qquad (2)$$

Where: Mρ = Multiplicative rescaling factor

Aρ = Reflectance_Add_Band

Qcal = Quantized and calibrated standard product pixel values (DN)

All the variables presented on the above equation could be accessed from the Metadata File, which was downloaded with the original images. The algorithm was used based on the calibration coefficients provided together with the data-sets in remote sensing environment using Harris ENVI-Environment For Visualizing Images (ENVI 4.4) software. The visible spectral bands of the Landsat OLI (Band 3 and 4) were used in order to retrieve chlorophyll-*a* over the Nandoni, Albasini and Vondo reservoirs.

3.4.4 Chlorophyll-*a* estimation from Landsat data

In estimating chlorophyll-*a* concentrations from reflectance values, spectral bands at 45 and 556nm are very important because that is where chlorophyll-a absorption is at peak while the lowest chlorophyll-a absorption is normally found at 520 and 550 nm (Dube, 2012; Dube et al., 2014). Based on this knowledge, this study employed the most popular chlorophyll-*a* estimation expression (Buditama et al., 2017) to derive estimates over Nandoni, Albasini and Vondo dam from atmospherically corrected Landsat OLI images. The following equation 3 was used to computes chlorophyll-*a* concentration:

Log Chl-a = (2,41*B4/B3) + 0,187………………………………………………………(3)

After deploying the above algorithm, an output was created on Harris ENVI software (Image view) with a Logarithm spectral reflectance values, therefore an anti-logarithm expression had to be introduced in order to remove the logarithm on the processed images to derive the accurate chl-*a* concentrations instead of Logarithmic Chl-*a* estimates. The following expressions (Equation 4 & 5) were employed as the anti-log:

Chl-*a* = 10^B3……………………………………………………………………………(4)

Chl-*a* = 10^B4……………………………………………………………………………(5)

3.4.5 Data Validation

The Chlorophyll-*a* In-situ data that was measured in the field on the 07 September 2017 was used to validate the Landsat 8 OLI which was acquired on the 26 of August 2017. The data was validated by comparing the concentrations of chlorophyll-*a* of two different dates in all reservoirs. The concentrations of chlorophyll-*a* for both field measurements and remotely sensed data were exported from ESRI ARCGIS 10.5 attribute table to Microsoft excel spreadsheet.

Kappa coefficient statistic method was used for validating the Field measurements and the pixel values retrieved from Landsat 8. Kappa measured inter-rater agreement for the two data sets collected and K value was computed using Microsoft excel. The following equation 6 was used to determine the significance of two variables which had a strong relationship.

$K = \frac{Po - Pc}{1 - Pc}$ ……………………………………………………………………………(6)

Where Po = Field Measurements

Pc = Remotely sensed values (Derived from anti-log expression)

K= Agreement Coefficient Value

The K values were then converted to percentage. From the results presented in Table 4.7, 4.8 and 4.9, it is reflected that the most of the values were above 0.8 which conclude that there is a best agreement between the field measurements and the remotely sensed data.

3.5 Data analysis

Microsoft word and excel 2016 was used to compute mean and standard deviations for all the replicated and to compute standard error bars. The mean values were then used to draw graphs representing the average results recorded in the field and during the experiments.

3.5.1 One Way ANOVA Analysis

Sample analysis of Banana peel powder, Potassium sulphate and control was done individually (Section 3.3.3) and analysis were subjected to ANOVA one-way statistical analysis of variance and determination of significance of results. The p values for Banana peel powder and K_2SO_4, Banana peel powder and Control, and lastly Potassium Sulphate and control were determined through ANOVA one way. The results from ANOVA were considered as accepting the null hypothesis presented earlier on this work since the p values were above 0.05.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Controlling the growth of Cyanobacteria in samples from Fish pond Using Banana peels Ash

We present the evidence showing the potential of Banana peels ash to inhibits the growth of algae on bench experiment through introducing the ash to the cyanobacteria suspension of BG11 medium.

4.1.1 BG 11 Solution experiment and inhibition of Cyanobacteria Suspension

Modified BG11 medium was laboratory prepared as per the method developed by Kruger and Eloff (1977) for cyanobacteria culturing. The medium was prepared using mineral composition shown in Table 4.1 and trace elements in Table 4.2. One 1000ml Erlenmeyer flask was filled with 850ml of deionized water, minerals and trace elements were also added to the flask. The solutions were shaken until the minerals were completely dissolved and mixed. The Erlenmeyer flask was then filled up to 1000ml with deionized water. The medium was autoclaved at 121°C for 15 minutes. 4ml of Cyanobacteria inoculum was added to Erlenmeyer flask containing 1000ml of modified BG11 medium under sterile condition. The culture was incubated for 30 days under continuous light (1100 lux) fluorescent lamps at room temperature (25°C).

The table below shows the mineral composition concentration needed to prepare the BG11 media for culturing cyanobacteria.

Table 4. 1: Modified BG11 mineral composition concentrations

Components	**Final Concentrations**
$NaNO_3$	1.500g
K_2HPO_4	0.040g
$MgSO_4.7H_2O$	0.075g
$CaCl_2.2H_2O$	0.036g
Citric acid	0.006g
Ferric ammonium citrate	0.006g
EDTA (disodium salt)	0.001g
Na_2CO_3	0.020g
Trace metal mix A5	1.0ml (from Table 4)

Table 4. 2: Trace metal solution

Component	**Final concentration**
H_3BO_3	2.860g
$MnCl_2.4H_2O$	1.810g
$ZnSO_4.7H_2O$	0.222g
$NaMoO_4.2H_2O$	0.390g
$CuSO_4.5H_2O$	0.079g
$Co(NO_3)_2.6H_2O$	49.40mg

4.1.2 Preparation of Banana Peels to Ash

Banana peels were collected and put on roof for drying on sun for 7days at temperature ranging from 28 to 38°C in Limpopo Province during summer season. After 7 days, 350 grams of dried banana peels were weighed, then burned with fire and grinded to powder using mortar and pestle (Figure 4.1). After grinding, the weight of banana peels was found to be 292 grams. The powder was then passed through 125µm sieve on a homogenous shaker in the laboratory.

Figure 4. 1: Showing the preparation of dried banana peels and burning banana peels using fire

4.1.3 Mineralogical characterisation

Table 4. 3: Showing the XRF (X-ray fluorescence) Results for Banana Ash and Potassium Sulphate before treatment (Concentration of Treating agents).

Treating Agents	**Concentrations**
Banana Ash	Average = 44.988w/w
Potassium Sulphate	Average = 31.697w/w

The amount of Potassium fertilizer and Banana peels powder to be added on the samples were measured according to (Gammal, 2008). The concentration of Banana peels powder was determined in XRF (X-ray fluorescence) in the Laboratory (Figure 4.2). 6mM of banana powder and K_2SO_4 analytical powder were added to the beakers containing cyanobacteria suspension of BG 11 medium. Prior the experiment, the average concentration of K_2SO_4 and Banana peels was found to be 31.697 and 44.988w/w respectively as shown in Table 4.3. It was detected that the banana peels had high concentration on Potassium than Potassium Sulphate as per the analysis by XRF.

Figure 4. 2: XRF analysis of K in banana Ash and Potassium Sulphate

4.1.4 Batch potassium treatment experiment

Batch experiment were carried out to evaluate the effect of banana peels and potassium sulphate in inhibition of growth of cyanobacteria in fish pond water. 200ml of sterile BG 11 was prepared in a fume-cardboard and was added to 1 litre of cyanobacteria suspension to make it 1200ml solution. The mixture was put on the 1800ml Erlenmeyer flask and shaken at 120rpm for 30minutes for homogeneity. 200ml of the solution was transferred to 6 times 250 glass beakers and each 250ml glass container was containing 200ml of the solution. Two by 250ml glass beakers with the solution were added with Potassium Sulphate, another two by 250ml glass beaker with the solution was added with Banana Peels powder and the last two glass beakers were added with nothing (control). The samples were incubated at room temperature under continuous fluorescent lamps at room temperature (25°C). The effect of the treatments was evaluated by varying the absorbance at 750nm on the spectrophotometer.

Figure 4.3 below shows the varying Absorbance (at 750nm) of two treatments and control in the laboratory.

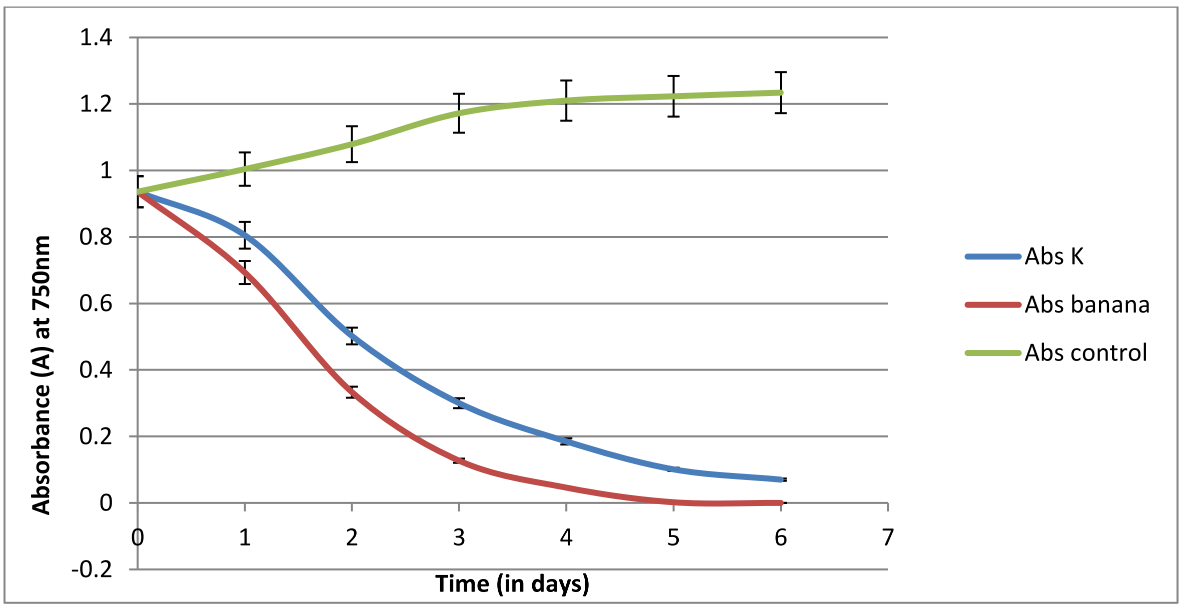

Figure 4. 3: Effects of Banana peels powder and K_2SO_4 on the growth of algae in BG11 medium.

The effect of potassium in banana peels on the growth of algal blooms was investigated under sterile condition, i.e., shaking of beakers containing cyanobacterial suspension. The cyanobacteria growth was monitored for 7 days under a continuous fluorescence light. All the beakers were sterilised and introduced with 6 mM concentration of Potassium to inhibit the growth of algae. The inhibitory effect of banana powder was quite distinct as the inhibition is observed from day 2 with 0.936 absorbance up to day 7 where absorbance is zero. The banana and K_2SO_4 treatments work at the same rate and produce similar impacts on the samples as compared to the control. Although the control experiment did not receive any chemical treatment, algal blooms on in those containers showed a continuous growth. This was probably because the container was still receiving enough light as a source of nutrient and not receiving inhibition solvents. Cyanobacteria cells are significantly reduced dur2ing 24 hours test period. From day 0, 1, 2, 3, 4, 5, 6 and 7 the absorbance showed a significant decrease for banana and K_2SO_4 and control as they were 0.936, 0.693, 0.333, 0.127, 0.046, 0.002, 0 and 0.936, 0.805, 0.502, 0.3, 0.185, 0.101, 0.07 and 0.936, 1.004, 1.079, 1.172, 1.21, 1.223, 1.234 respectively. In day 7, the absorbance on the treated samples were found to be zero while in the controlled sample, the algae continued to grow.

Potassium fertilizer have been previously used effectively for inhibiting the growth of cyanobacteria in fish ponds (Gammal, 2008). Figure 4.3 demonstrate a positive inhibition effect on cyanobacterial blooms where the algal blooms were exposed to 6Mm concentration of potassium sulphate and banana peels powder. It can further be concluded that banana peels powder contained high concentration of potassium as attested on XRF analysis of banana before experiment. It was found that the concentration potassium in banana peels powder was higher as it recorded 42.988w/w as compared to the concentration of potassium sulphate which recorded 31.697w/w. From the above account, it was observed during the experiment that algal cell on banana treatment are dying faster than the treatment where potassium sulphate was used. Appendix B shows the results of physicochemical parameters analysed in the laboratory on the batch experiment of Banana Peels powder, Potassium Sulphate treatment and its control samples.

4.1.5 Anova Analysis

The one-way ANOVA statistical analysis was used to determine the significance and acceptance of null hypothesis of the experiment between Banana peel powder and K_2SO_4, Banana peel powder and Control, and lastly Potassium Sulphate and control. The results showed great acceptance of hypothesis between the Banana peel powder and K_2SO_4 where $p = 0.6$. There is no significance difference between the effect of the Banana peel powder and Potassium Sulphate in inhibiting the growth of cyanobacteria.

Based on one-way ANOVA statistical analysis, the results showed $p = 0.04$, where there is a significance difference between banana peel powder and control. Thus, banana peel powder was able to inhibit the growth of cyanobacteria. Secondly, the one-way ANOVA statistical analysis showed $p = 0.03$, where there is a significance difference between potassium sulphate fertiliser and control. Thus, potassium sulphate was able to inhibit the growth of cyanobacteria. Banana peel powder was a better inhibitor in comparison with potassium sulphate fertiliser (Figure 4.3).

4.2 Physico-chemical characteristics of batch treatment experiment

The Physico-chemical parameters are important components for assessing the water quality in pond waters. It is very significant to analyse physical and chemical characteristics of water so to determine the pollution status of a particular water body. In fact, the status of a particular water body is normally conditioned by these factors and as such the quality of water is determined by the results of these factors. It is well recommended that fish and other aquatic animal shall live in water that is favourable and free from contamination either by humans or naturally.

The following figure 4.4 to 4.8 showed analysis results of pH, EC (µs/cm), TDS (mg/L), Temperature(°C) and DO (mg/L) for treatment and control for 7 days experiments. The results showed a significant difference in DO, EC and TDS content between day 2 and day 7.

4.2.1 Electric Conductivity

Conductivity Reflects the amount of soluble salts in water. It further reveals the nutrient content of the water and distribution of microphytes. High values of EC (86.4 and 87.9 µS/cm) have been observed in both Banana peels and K_2SO_4 treatment as compared to control samples which had readings ranging from 59.9 to 70.0 µS/cm (Figure 4.4). The reason for high values is probably derived from the BG 11 created medium which had high concentration of salts as per preparation procedure of Kruger and Eloff (1977). The low values of conductivity in the present study may be due to the silt content present in the sample.

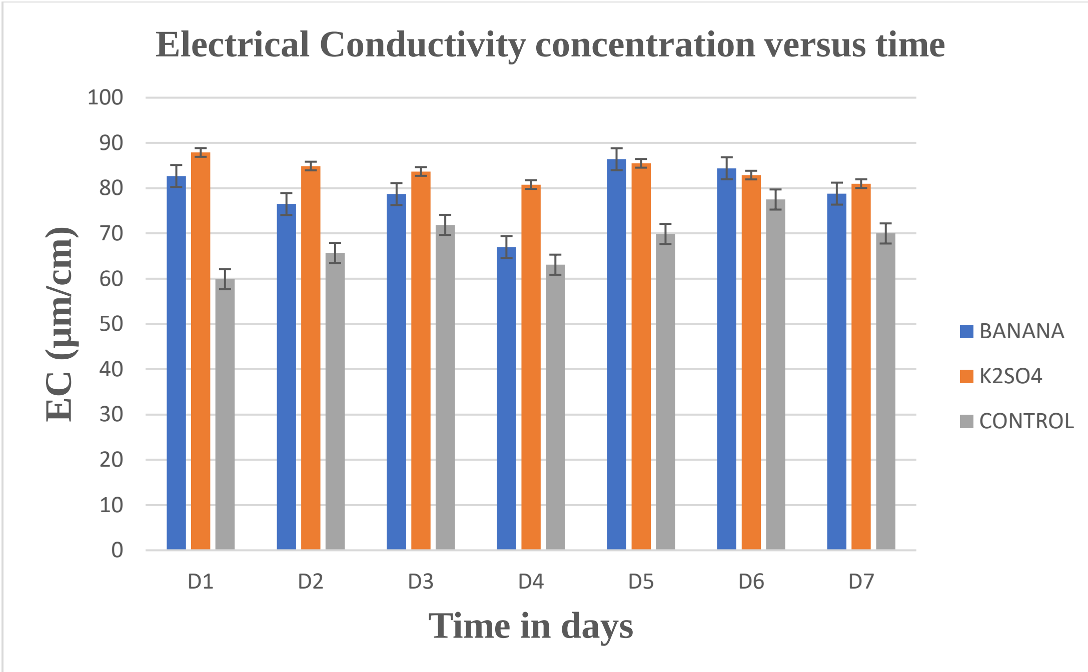

Figure 4. 4: Showing the concentration of Electrical Conductivity for 7 days experiment

4.2.2 Water Temperature

Water temperature is highly influenced by a steady change in atmospheric temperature with the change in seasons. (Welch, 1952) mentioned that small bodies react very quick with change in atmospheric temperature. It was further mentioned that high summer temperature accelerates the decay of organic matter process which result into liberating large quantities of carbon dioxide in the atmosphere and high nutrients content in the soils. These nutrients might end up in the water bodies deteriorating water quality. High temperatures also lead to the speeding up of the chemical reaction in water and reduces the solubility of gases and amplifies the tastes and odours. Temperature is also very important in determining various parameters such as pH, electric conductivity, alkalinity and some few elements.

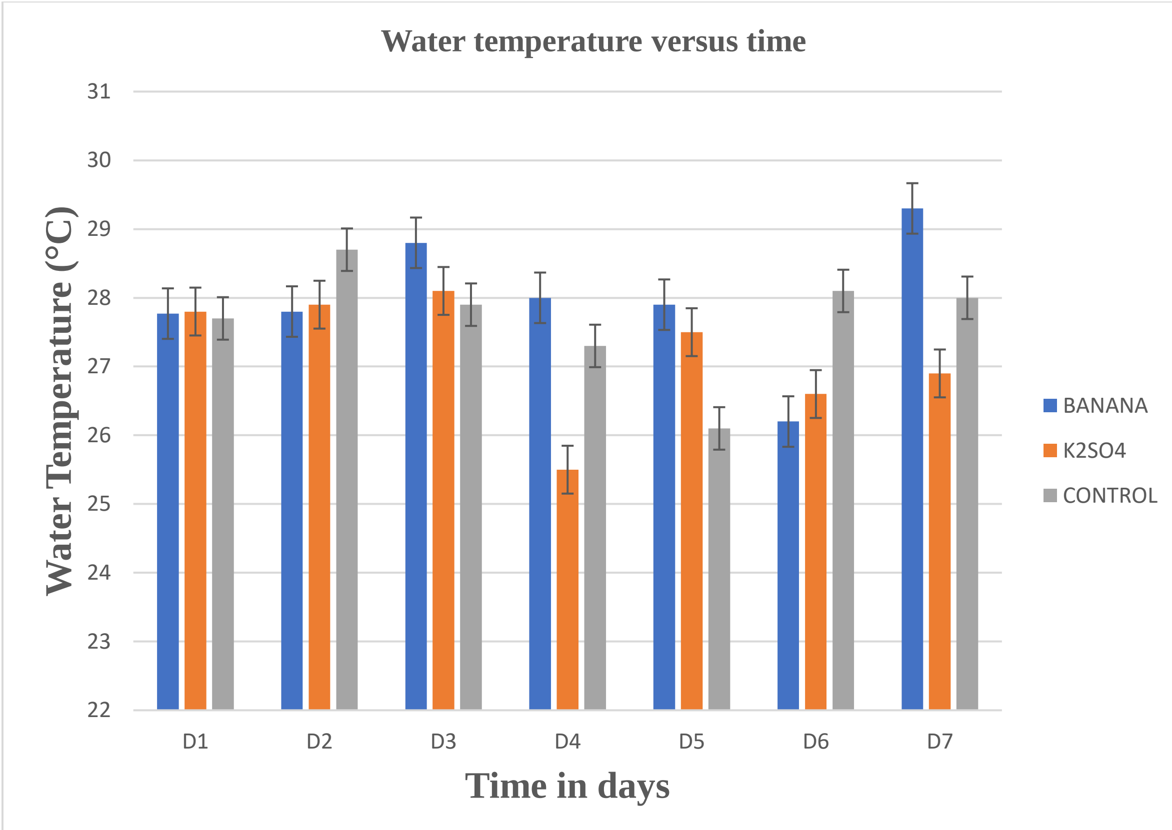

Figure 4. 5: Showing water temperatures for 7 days experiment during treatment of cyanobacterial blooms in the laboratory.

. From the graph above, it can be observed that the temperature of water during the experiment remained constant (26°C and 27°C) with slight decline of 25°C during day 6 in all treatment and control (Figure 4.5). This was due to the slight decline in atmospheric temperature at day 6. For freshwater aquaculture, the suitable range of temperature is about 25-32°C (Munni et al., 2013). It is concluded that the temperature for all experiments was suitable for aquatic organisms to survive on it.

4.2.3 Total Dissolved Solids (TDS)

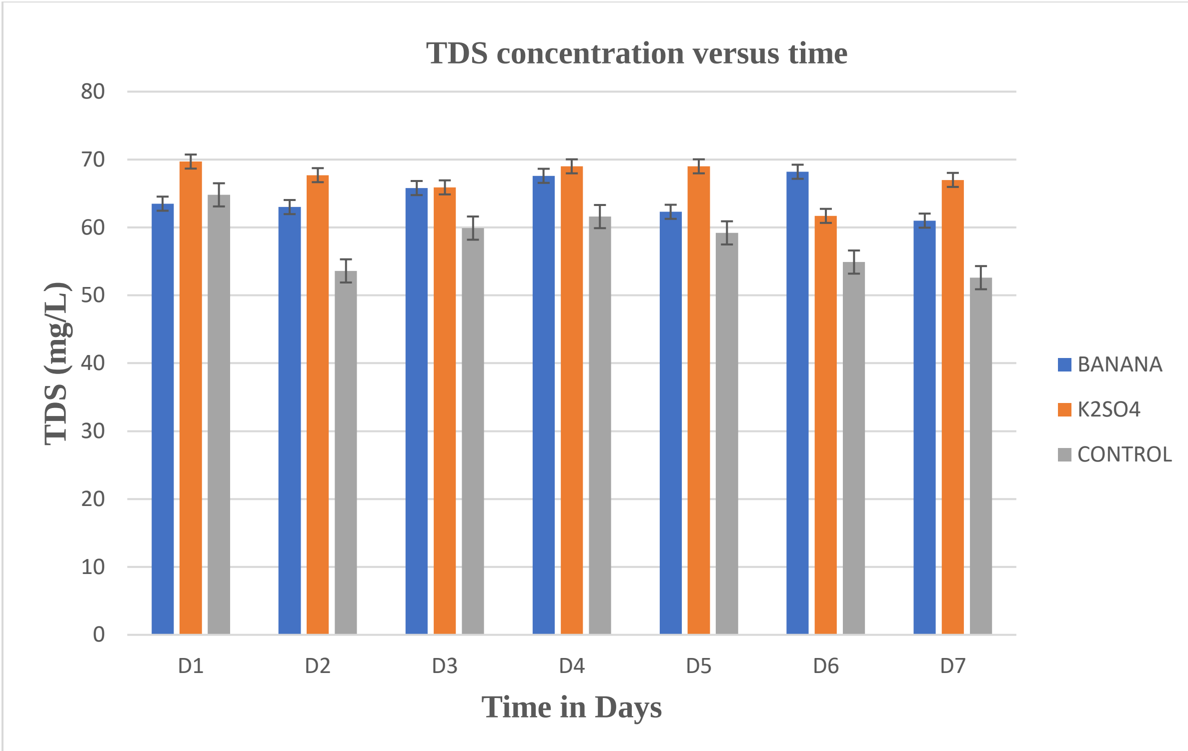

Figure 4. 6: Showing the concentration of Total Dissolved Solids for 7 days experiment

Dissolved solids are a crucial parameter in water quality for drinking purposes and aquatic environments. They provide taste to the water and reduces its palatability. Suspended solids can cause ecological imbalances in the aquatic environment by mechanical abrasive action (Munni et al., 2013). High loads cause deterioration of water quality and reduce the live span of aquatic organisms. Suspended solids may be in the form of course, fine, floating and settling materials/particles inside a water media. In the present study, the values of TDS were found to be 60mg/L in treatment experiments and 50mg/L in control experiment (Figure 4.6). According to DWA water guidelines standard, the values are within the recommended range for drinking and suitable for fish lives. In fish culture, the presented values of TDS are permissible for diverse fish production.

4.2.4 pH

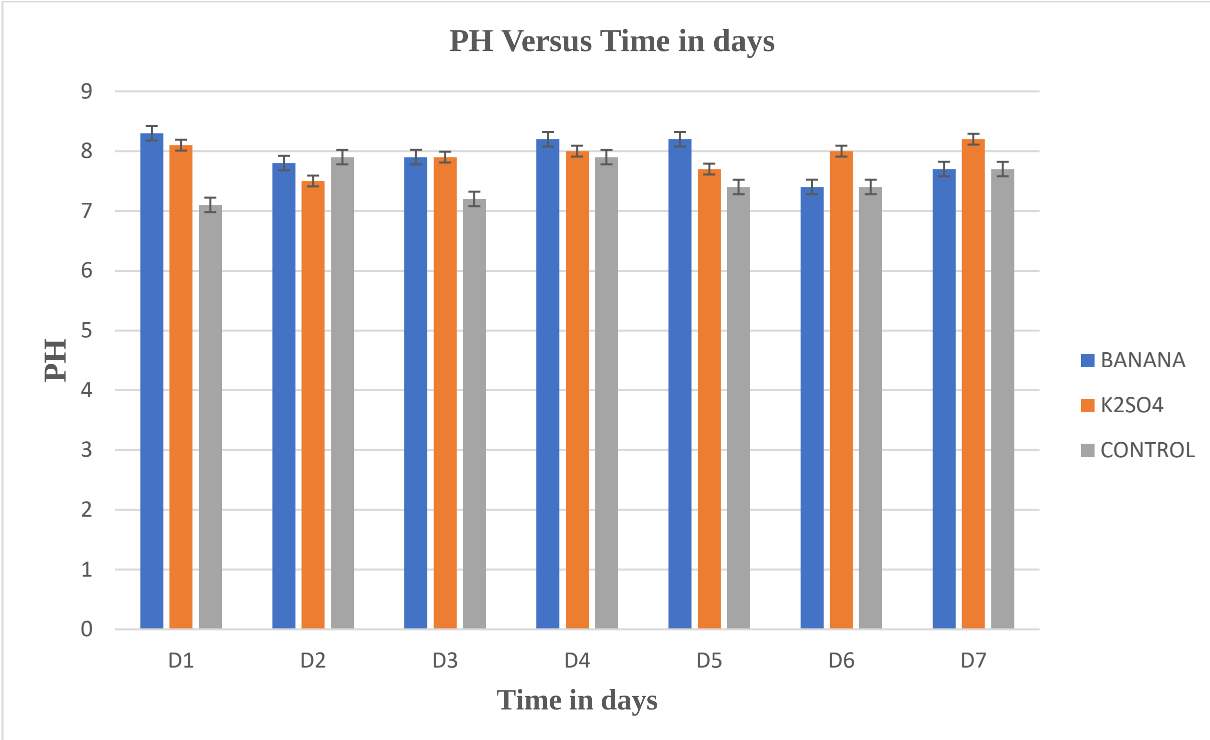

Figure 4. 7: Showing the pH concentration for 7 days experiment during treatment of cyanobacterial blooms.

In the present study, pH has shown decrease on the control with decrease in temperature. The decrease in pH during low temperatures may be due to decrease in the photosynthesis process, while during 27 – 28°C the pH values remained constant in both treatments. The recorded pH maximum value during the experiment was found to be 8.3 banana treatment and 8.2 in K_2SO_4 treatment (Figure 4.7). These maximum values of pH may be due to increase in photosynthesis of the algal blooms resulting into the precipitation of carbonates of calcium and magnesium from bicarbonates causing high alkalinity in water. The fluctuation in pH values was very small, which was favourable for growth of algae in the treated and controlled glass containers. The reading clearly indicates a narrow change in the batch experiments throughout the days and water was found to be slightly alkaline in all cases.

4.2.5 Dissolved Oxygen

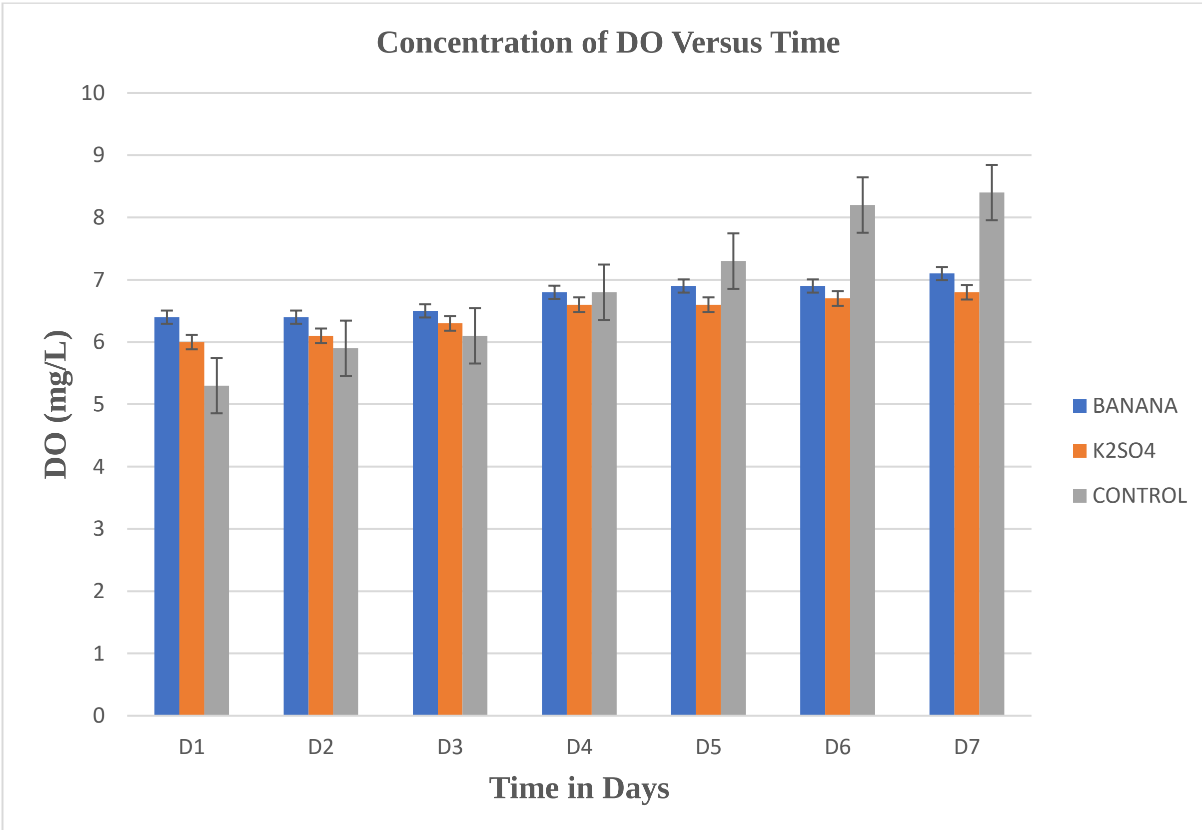

Figure 4. 8: Showing the Dissolved Oxygen concentration for 7 days experiment during treatment of cyanobacterial blooms.

Dissolved oxygen is a critical characteristic of water quality and index of physical and biological process which is going on in water. One of the sources of DO in water is photosynthetic activity within the water. Photosynthetic activity depends upon autotrophic population i.e. mainly phytoplankton in water, light condition and available gases. From the results above, DO has showed a slightly stable readings along the entire experiment period. On the analysed reading from the table above, it was found that the lowest reading was 6.4, 6.0 and 5.3 mg/L for banana, K_2SO_4 and control respectively (Figure 4.8). In the present study, there was a definite trend in DO concentration on all treatments and there was a slight variation in terms of time interval from introducing a treatment in the samples. An approximate trend was observed on the results during day 7 for banana, K_2SO_4 and control treatment, where the concentration was higher at 7.1, 6.8 and 8.4 mg/L respectively. Generally, the values of DO was found to be increasing with the growth of cyanobacteria in the containers. Nevertheless, natural water bodies saturated with DO make aquatic environment to be conducive for fish lives.

4.3 Chlorophyll-*a* and Turbidity results

Water samples were collected from the fish ponds which are dominated by algal scums. Chlorophyll-*a* was measures spectrophotometrically to determine the levels of algal blooms together with algal biomass in the aquaculture ponds. In this study, turbidity was also analysed to determine the cloudiness of water in the fish ponds. Tshifulanani and Lwamondo fish ponds have been studied previously to determine the cyanobacteria species which are present. Studies shows that the ponds have cyanobacteria species such as *Anabaena* and *Microcystis* (Tshifura et al., 2018). According to (UNECE, 1994) chlorophyll-*a* concentration has a maximum range for aquatic ecosystems which is 110 µg/L while fish can survive at a turbidity of 20 NTU.

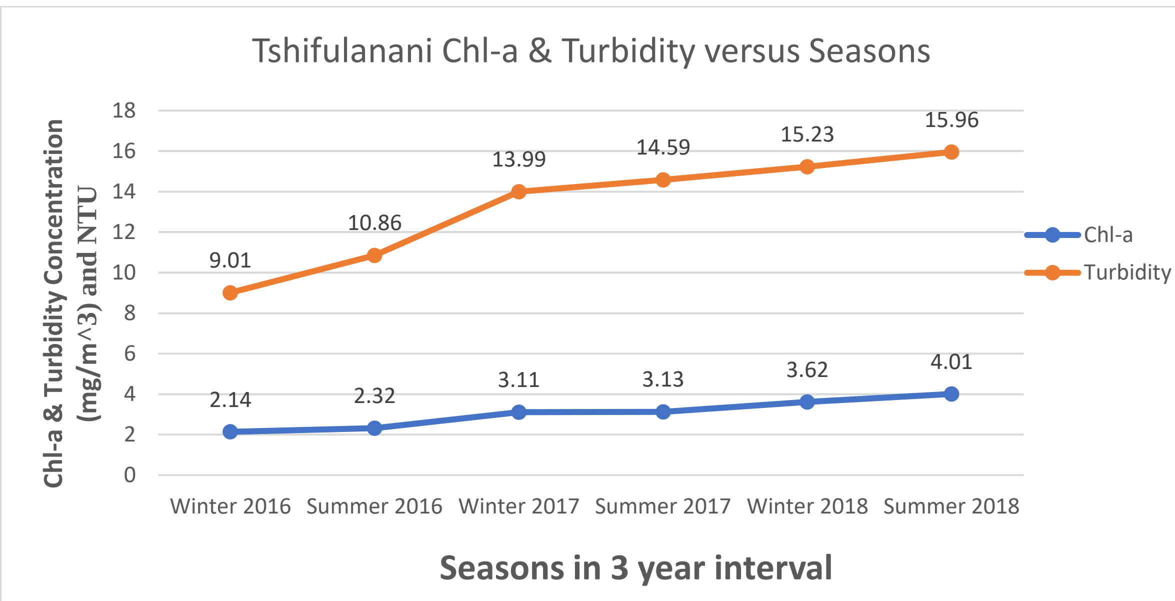

Figure 4. 9: Showing the concentration of Chlorophyll-*a* at Tshifulanani Pond for different seasons from 2016 to 2018.

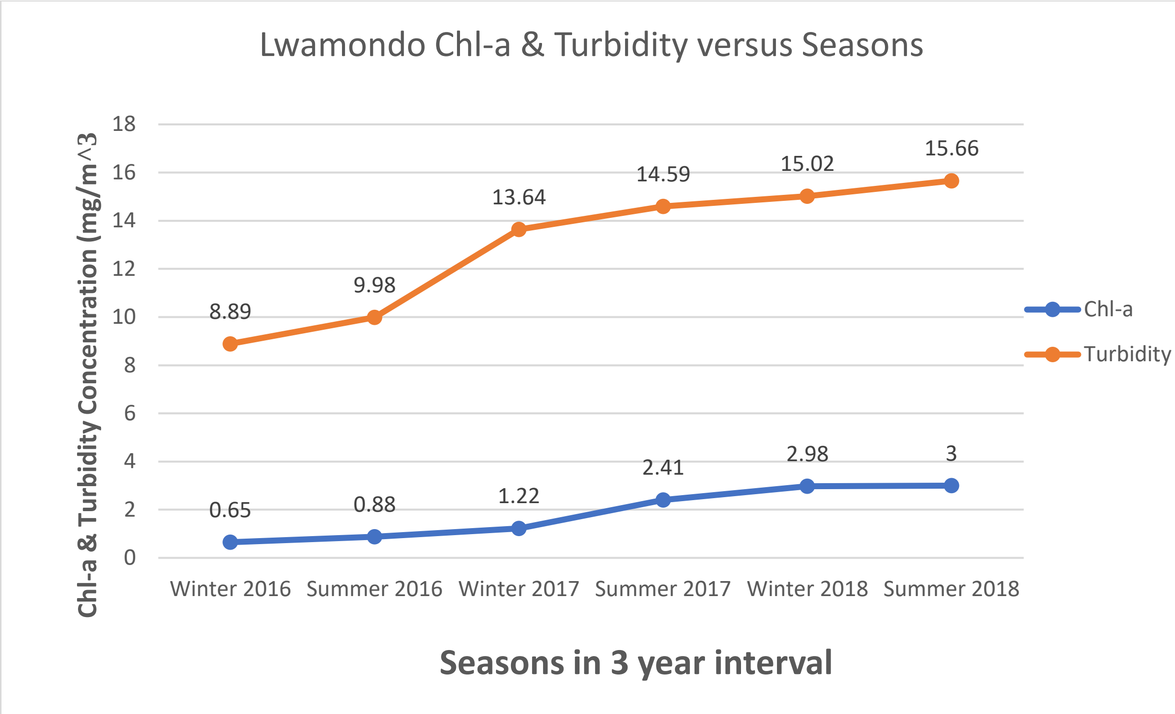

Figure 4. 10: Showing the concentration of Chlorophyll-*a* at Lwamondo fish Pond for different seasons from 2016 to 2018.

4.3.1 Chl-*a* and Turbidity results discussion

4.3.1.1 Chlorophyll-*a*

Chlorophyll is mainly used to measure the quality of water and its concentration is an indicator of algal abundance and productivity in aquatic ecosystems. High concentrations of chlorophyll-*a* normally indicate poor water quality whereas lower concentrations typically indicate good water quality. The presence of high concentration of chlorophyll is usually associated with high nutrient concentration in water bodies. The results of chlorophyll-*a* in both ponds reveals that chl-*a* increase as cyanobacteria grows in fish pond. The increase of chl-*a* depends on several factors such as the presence of nutrients in water and the amount of sunlight entering the pond. This is shown by the concentration of chl-*a* which is increasing from year to year not considering seasonal variation (Figure 4.9 and 4.10). The concentration of chl-*a* at Tshifulanani and Lwamondo ponds has increased from 2.14 and 0.65 mg/m^{-3} in 2016 to 4.01 and 3.0 mg/m^{-3} in 2018. However, these concentrations are very low and does not pose any negative implications on fish. The chlorophyll content in the ponds were observed and might be due to introduction of fish feeds which normally have nutrients such as Nitrogen and phosphorus which encourage the growth of algae in aquaculture ponds. In conclusion, the Tshifulanani ponds has shown a rapid growth of algae since in 2018 as it recorded chlorophyll concentration of 4.01 mg/m^{-3} while Lwamondo pond has recorded 3.0 mg/m^{-3}. There is over feeding of fish which is suspected in Tshifulanani pond because of high levels of chl-*a* and average feeding which is being applied in Lwamondo fish pond.

4.3.1.2 Turbidity

Turbidity is a striking component to know the physical status of water in a water body. It determines the suspended solids and organic matter present in the water sample from various sources. Turbidity determines the clearness of water which allows fish and other aquatic organisms to move freely in their environment. In this study, we observed a gradual increase in the concentration of turbidity in both Tshifulanani and Lwamondo fish ponds. Minimum value of turbidity was recorded for both ponds during three-year interval and they were 0.65 and 8.89 NTU for Tshifulanani and Lwamondo fish ponds respectively. Figure 4.10 has shown a significant change in turbidity concentration during winter 2016 and 2017 from 8.89 to 13.64 NTU. The increase in turbidity is normally associated with the increase in suspended matter and microbial growth in water.

4.4 Remote Sensing and In-situ Measurements Results and Discussion

Figure 4.11 shows the maps of chlorophyll-*a* concentration estimated by the model where Red and Green band ratios were used. The model used in this study had shown the potential of estimating chlorophyll-*a* concentration in dams with the positive pixel values. The pixels were not represented in the maps 9 (Figure 4.11) but the classes represented on the images were derived from the empirical model used by Buditama et al. (2017).

From the image classes shown on Figure 4.11, 2016 Images in all reservoirs showed very low concentration of chlorophyll-*a*, however Landsat 8 OLI was able to map algal blooms in the respective reservoirs. In the reservoirs, distribution of chlorophyll-*a* varies spatially and temporally. It can simply be observed that during summer 2016, the concentration of chlorophyll-*a* was very low as compared to summer 2018 at Nandoni dam. However, the algal abundance was remotely sensed at the edges of the dam. From the observation of the images in figure 4.11, spatial distribution of low algal content was observed in the middle of the Nandoni dam in the year 2018 while in 2016 there were no algal blooms detected. Vondo dam revealed no algal bloom content from 2016 to 2018. This shows that Vondo dam has not been impacted by cyanobacterial blooms for the period of 3 years. The concentration of chlorophyll-*a* in Vondo dam ranged from 0.0 to 0.3 $mg.m^{-3}$.

In Nandoni and Albasini dams, the chlorophyll-a had higher values on the area near the dam wall and dam edges while getting lower in the middle of the dam. This statement is based on sample data P9, P11, P17 and P19 which are nearest samples to the edges and in the middle of the dam. The dominance of chlorophyll-a is mainly caused by the few nutrients which are washed from agriculture, mining and other industries and deposited on the edges of the dams. This results in a rapid growth of algae where there is high accumulation of nutrients (at the edges of the dams). The temporal variations of chlorophyll-a concentrations are mainly caused by rainfall which tempers with runoff as the main supplier of algal blooms (Buditama et al., 2017).

From figure 4.11, it was also observed that besides detection of algal blooms in water, classification methods has revealed vegetation which is out of the dams being detected as algae since plants contains the chlorophyll pigment. This study only accounts for algae chlorophyll-a which is inside the water as attested by the field measurements.

Overall, from the results obtained from the remotely sensed and the In-situ measurements, it can be concluded that the three reservoirs have not been affected by high concentration of chlorophyll between the year 2016 and 2018. Since all the data discussed in this study was acquired during summer periods with low rainfall, this maybe the reason for low chlorophyll concentration in the dams because of low rainfall which normally carry nutrients to the water bodies which facilitate algal growth.

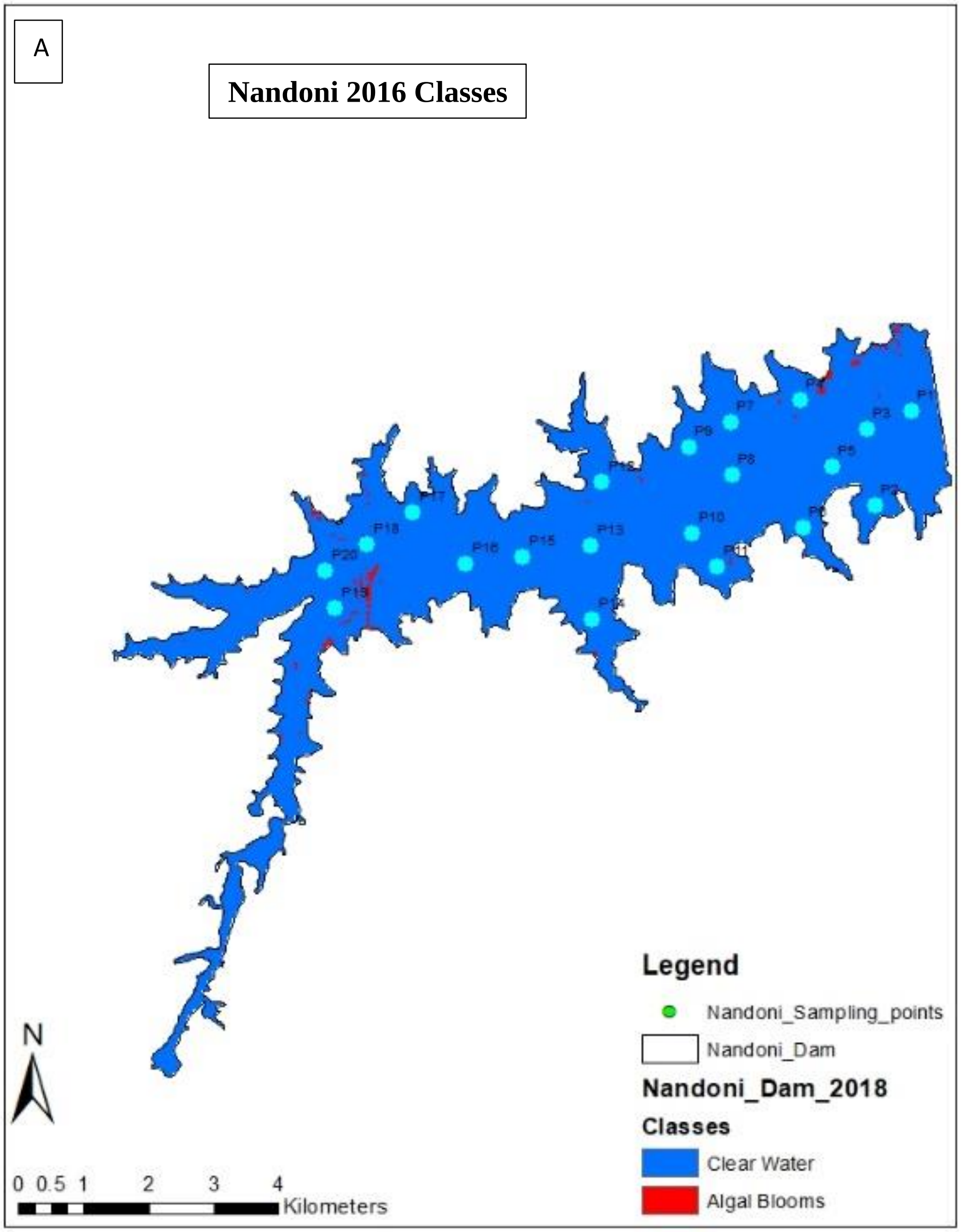

Figure 4. 11: Showing chlorophyll-a distribution map as two classes of features in the in the Nandoni dam during 2016 in Vhembe District, Limpopo Province.

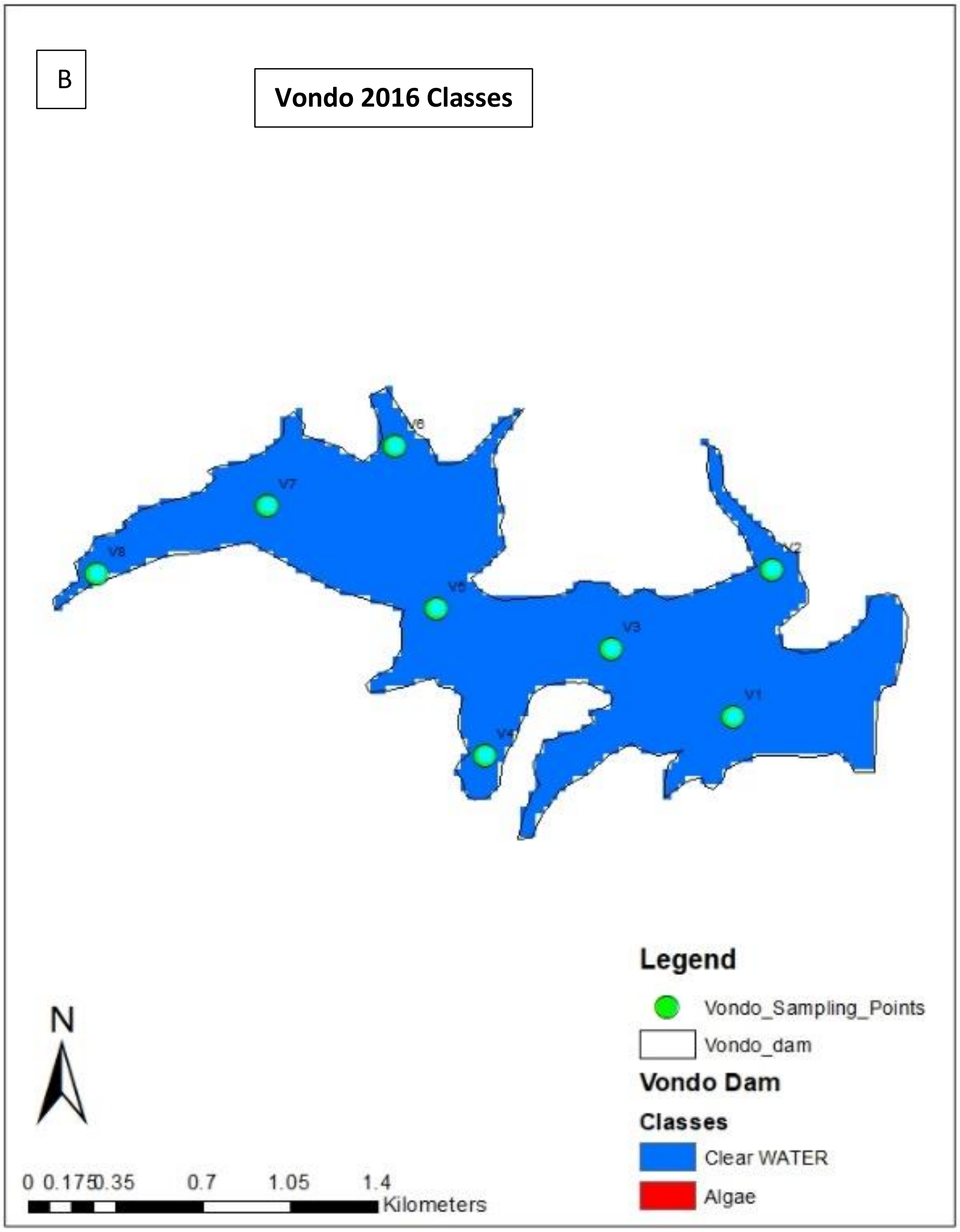

Figure 4. 12: Showing chlorophyll-a distribution map as two classes of features in the in the Vondo dam during 2016 in Vhembe District, Limpopo Province.

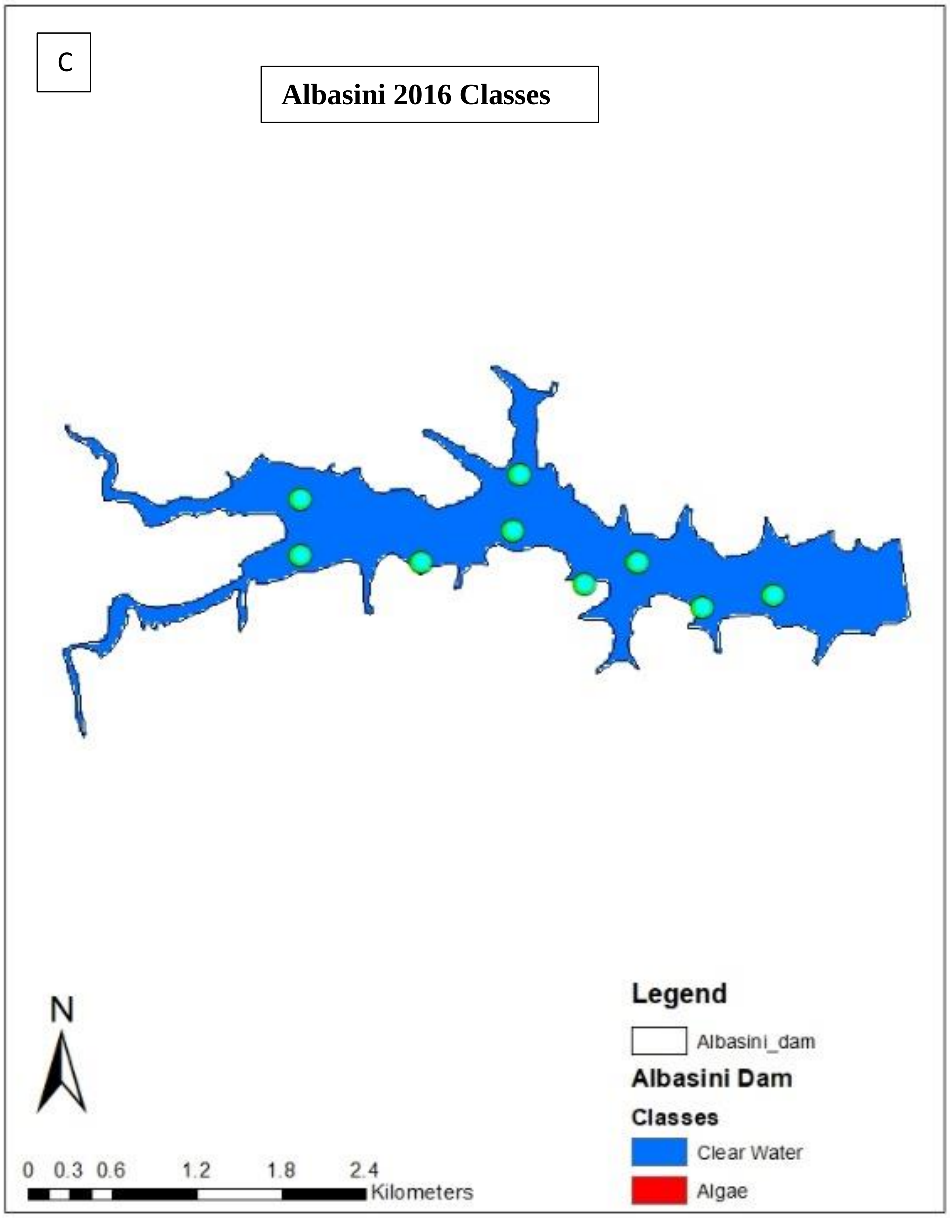

Figure 4. 13: Showing chlorophyll-a distribution map as two classes of features in the in the Albasini dam during 2016 in Vhembe District, Limpopo Province.

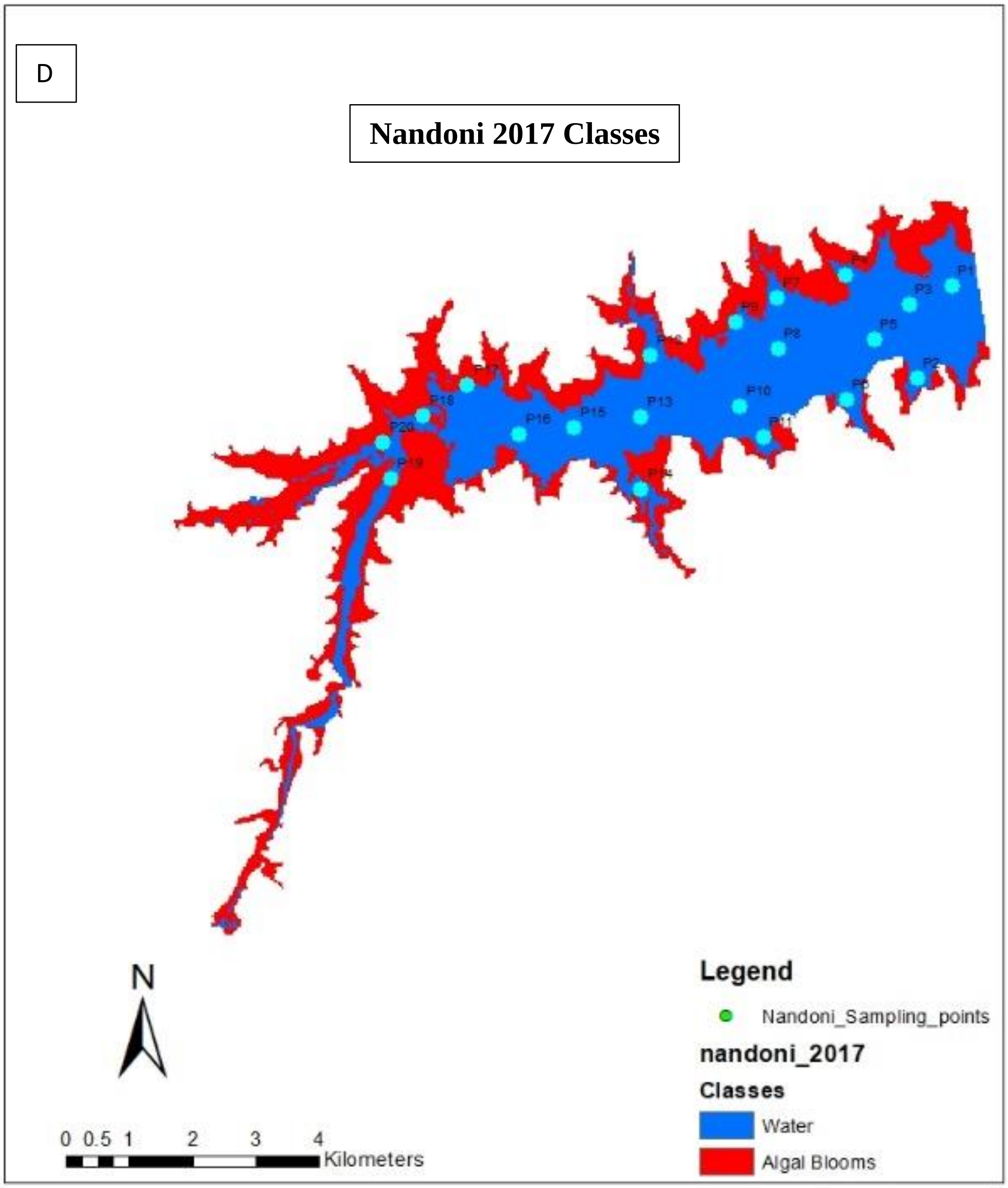

Figure 4. 14: Showing chlorophyll-a distribution map as two classes of features in the in the Nandoni dam during 2017 in Vhembe District, Limpopo Province.

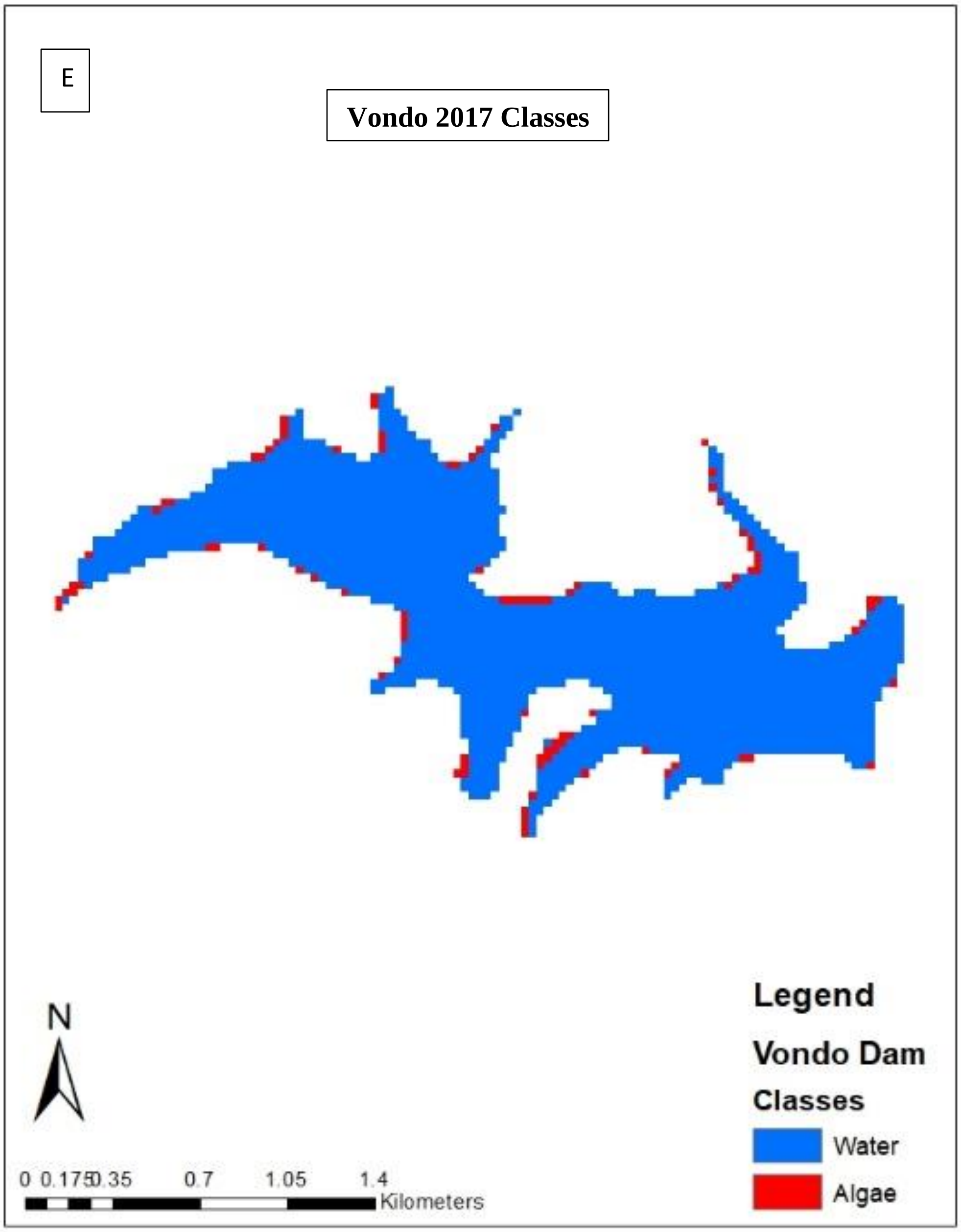

Figure 4. 15: Showing chlorophyll-a distribution map as two classes of features in the in the Vondo dam during 2017 in Vhembe District, Limpopo Province.

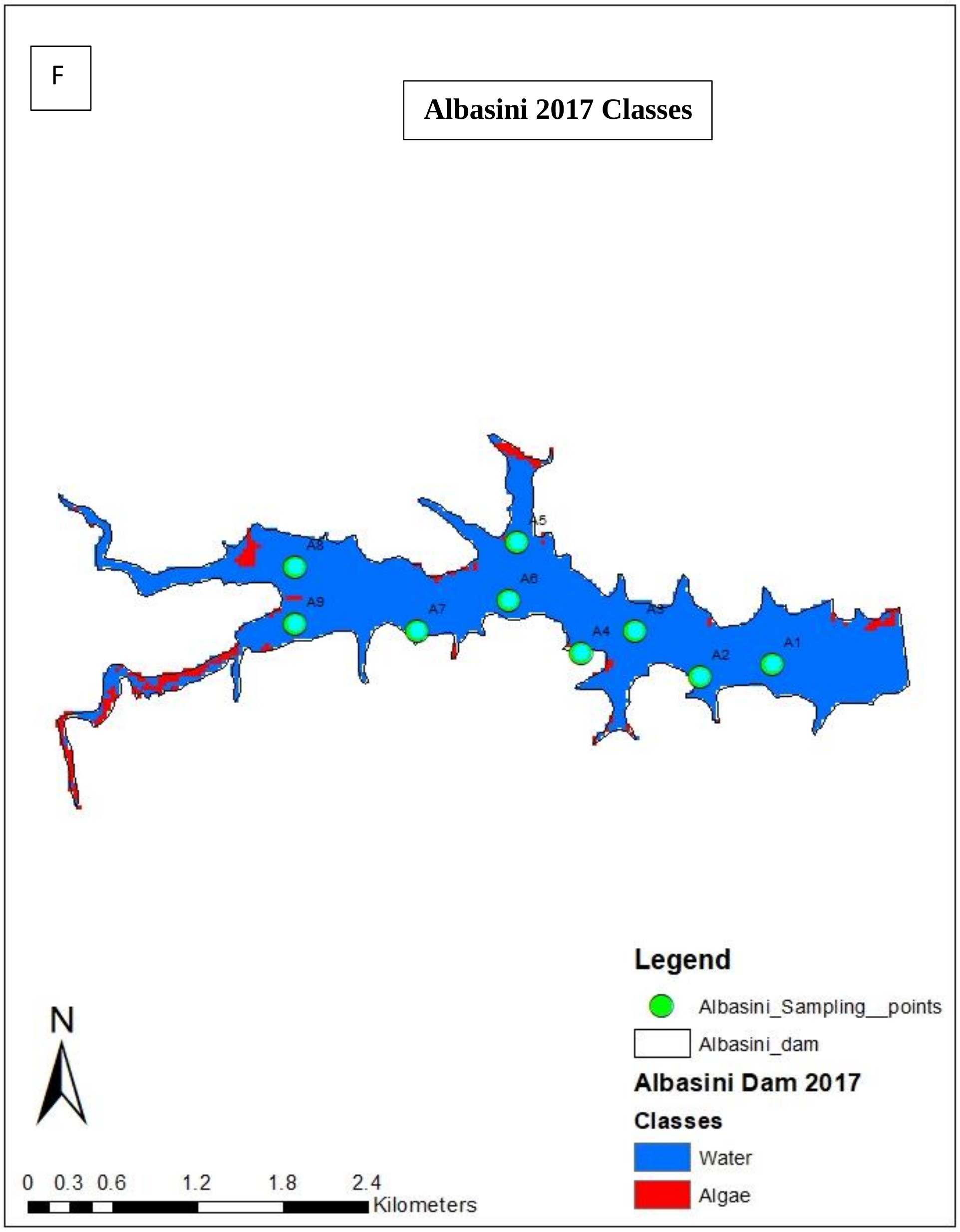

Figure 4. 16: Showing chlorophyll-a distribution map as two classes of features in the in the Albasini dam during 2017 in Vhembe District, Limpopo Province.

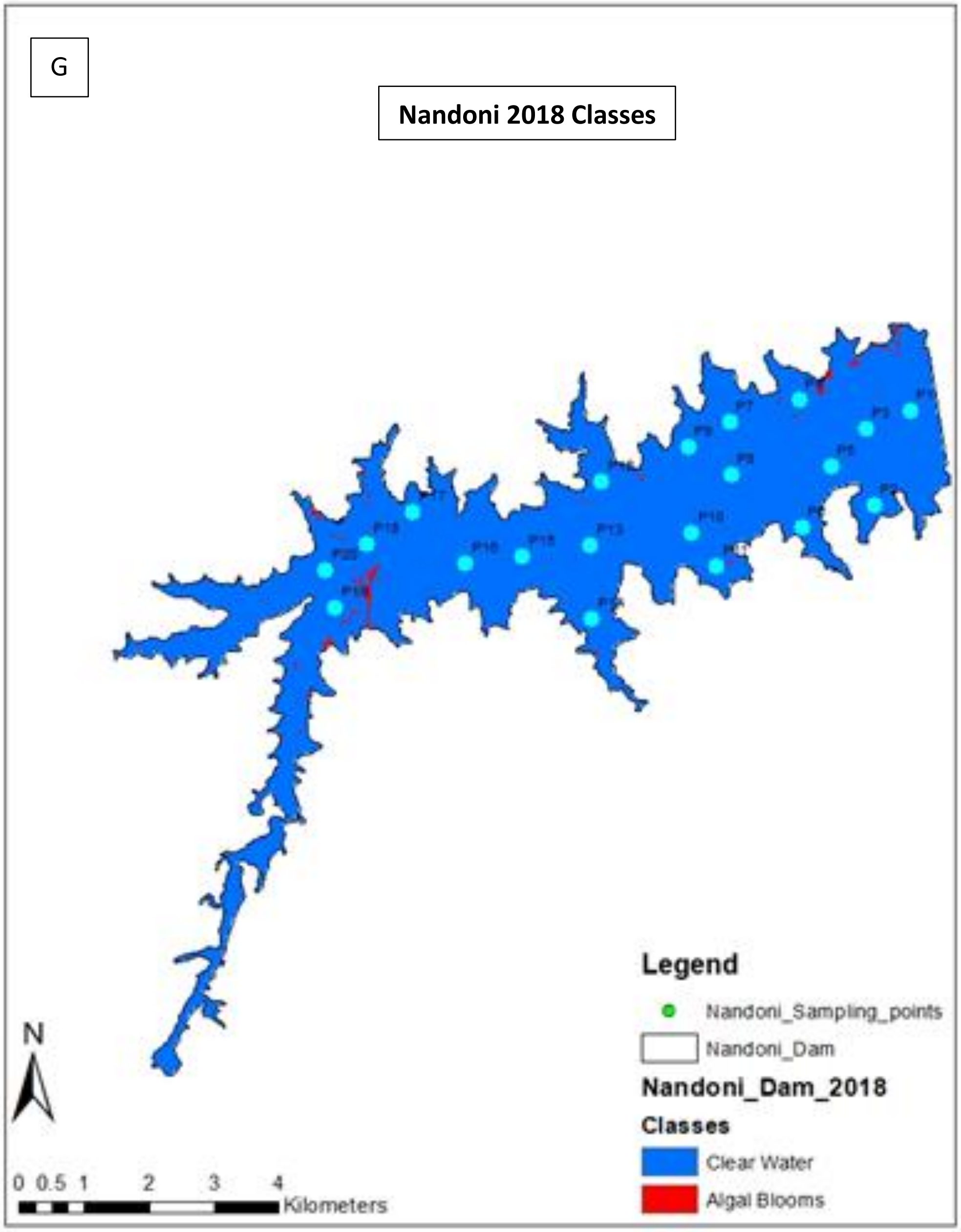

Figure 4. 17: Showing chlorophyll-a distribution map as two classes of features in the in the Nandoni dam during 2018 in Vhembe District, Limpopo Province.

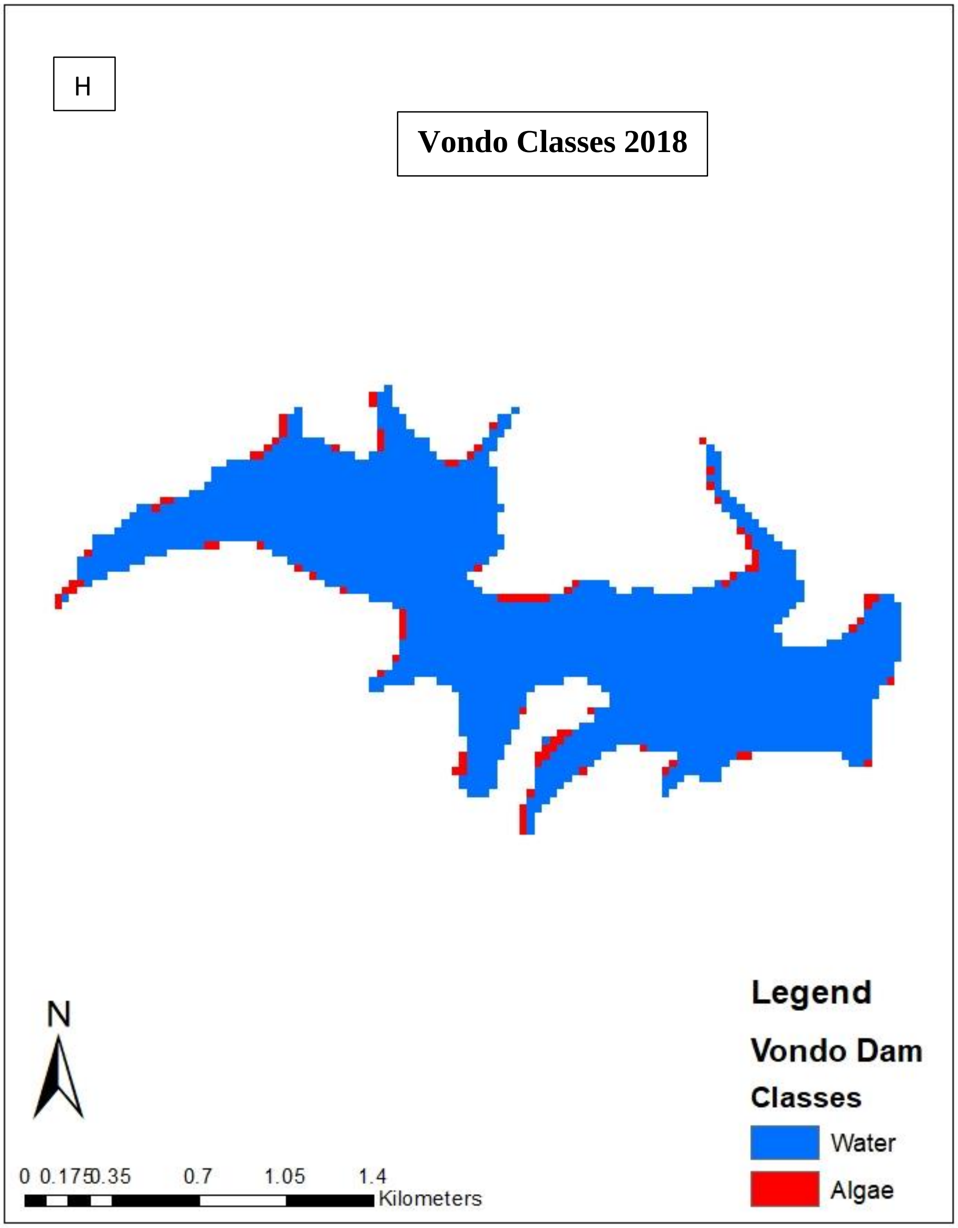

Figure 4. 18: Showing chlorophyll-a distribution map as two classes of features in the in the Vondo dam during 2018 in Vhembe District, Limpopo Province.

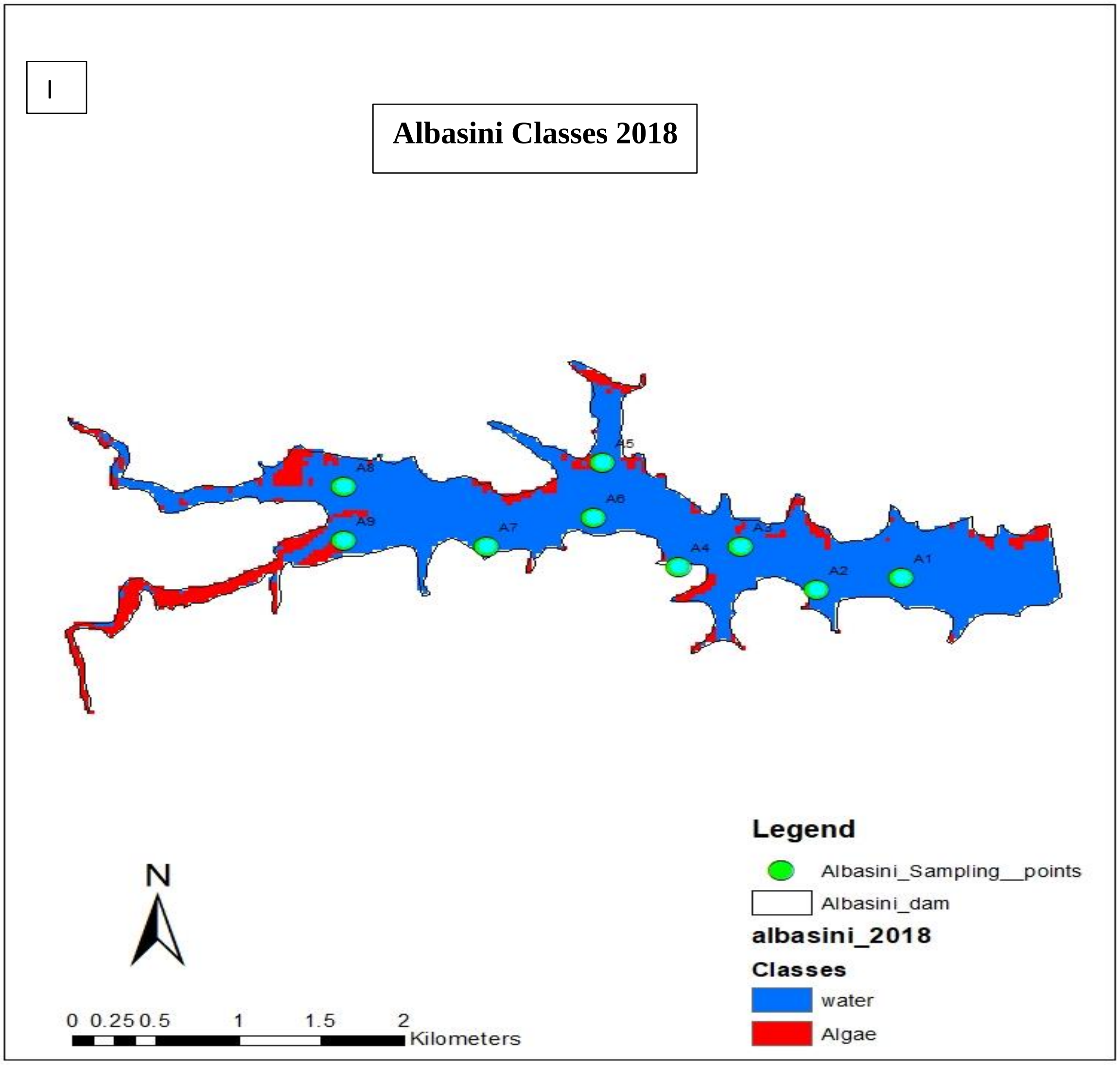

Figure 4. 19: Showing chlorophyll-a distribution map as two classes of features in the Albasini dam in Vhembe district, Limpopo province.

Figure 4.11- 4.19: Showing chlorophyll-a distribution map as two classes of features in the Nandoni, Albasini and Vondo dams in Vhembe district, Limpopo province from the remotely sensed and Laboratory analysis, we have observed a strong correlation of pixel values derived from chlorophyll-a estimates and chlorophyll-a values analyzed in the lab. The correlation is positive because the increase in one value of chlorophyll estimates from Landsat is an increase in the Lab data while decrease of Landsat pixel value is also a decrease in Chlorophyll lab results. This study demonstrates the potential of Landsat 8 OLI images on mapping areas with high and low concentration of chlorophyll-a. The spatio-temporal variation in the concentration of chlorophyll-a within the dams likely reflects the yearly and physicochemical factors influences. Chlorophyll estimates of all dams derived from Landsat OLI images were very low for most part of the dams which is attributed to decreased water level in the Nandoni, Vondo and Albasini dam (Dalu et al., 2015).

Table 4. 4: Showing the concentrations of chlorophyll-a for Laboratory analysis and remotely sensed data in Albasini dam during 2017.

Sample Number (Albasini Dam)	Field Measurements. Chlorophyll-a concentration ($mg.m^{-3}$)	Remotely Sensed (Anti-Log extracted values)	KAPPA Index Value
A1	0.9	0.5	0.80 (80%)
A2	0.8	0.1	0.78 (78%)
A3	0.8	0.2	0.75 (75%)
A4	0.9	0.5	0.80 (80%)
A5	0.7	0.1	0.67 (67%)
A6	0.6	0.4	0.33 (33%)
A7	0.9	0.1	0.89 (89%)
A8	0.9	0.4	0.83 (83%)
A9	0.9	0.2	0.88 (88%)

Table 4. 5: Showing the concentrations of chlorophyll-a for Laboratory analysis and remotely sensed data in Nandoni dam during 2017.

Sample Number (Nandoni Dam)	Field Measurements. Chlorophyll-a concentration (mg.m^{-3})	Remotely Sensed (Anti-Log extracted values)	KAPPA Index Value
P1	0.8	0.2	0.75 (75%)
P2	0.8	0.2	0.75 (75%)
P3	0.9	0.5	0.80 (80%)
P4	0.7	0.1	0.67 (67%)
P5	0.8	0.5	0.60 (60%)
P6	0.3	0.2	0.13 (13%)
P7	0.8	0.3	0.71 (71%)
P8	0.9	0.1	0.89 (89%)
P9	0.8	0.3	0.71 (71%)
P10	0.7	0.1	0.67 (67%)
P11	0.8	0.2	0.75 (75%)
P12	0.7	0.1	0.67 (67%)
P13	0.7	0.1	0.67 (67%)
P14	0.6	0.5	0.20 (20%)
P15	0.9	0.5	0.80 (80%)
P16	0.8	0.2	0.75 (75%)
P17	0.9	0.5	0.80 (80%)
P18	-	-	-
P19	0.8	0.6	0.50 (50%)

Table 4. 6: Showing the concentrations of chlorophyll-a for Laboratory analysis and remotely sensed data in Vondo dam during 2017.

Sample Number (Vondo Dam)	Field Measurements. Chlorophyll-a concentration (mg.m^{-3})	Remotely Sensed (Anti-Log extracted values)	KAPPA Index Value
V1	0.9	0.1	0.89 (89%)
V2	0.9	0	0.90 (90%)
V3	0.8	0	0.80 (80%)
V4	0.8	0.2	0.75 (75%)
V5	0.7	0.1	0.67 (67%)
V6	0.8	0	0.80 (80%)
V7	0.9	0.5	0.80 (80%)

V8	0.9	0.4	0.83 (83%)
V9	0.7	0.2	0.63 (63%)

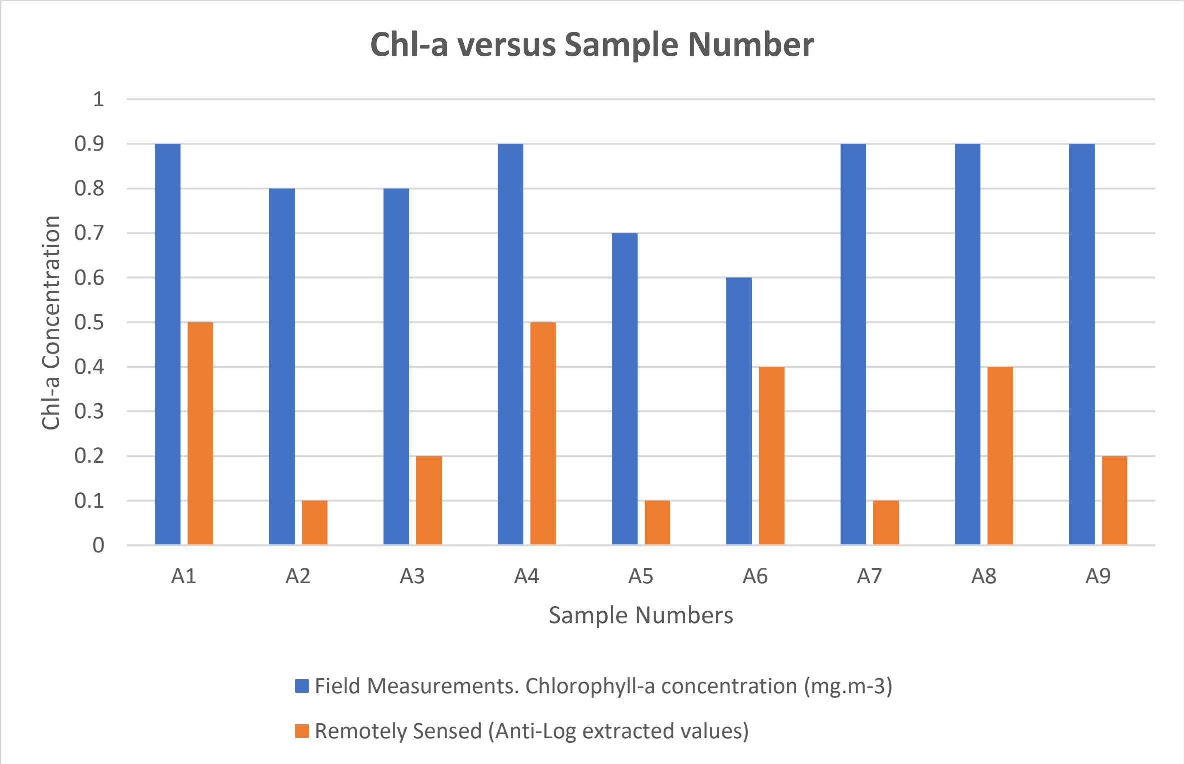

Figure 4. 20: Showing concentration of Chlorophyll-a for field measurements and remotely sensed data for Albasini dam

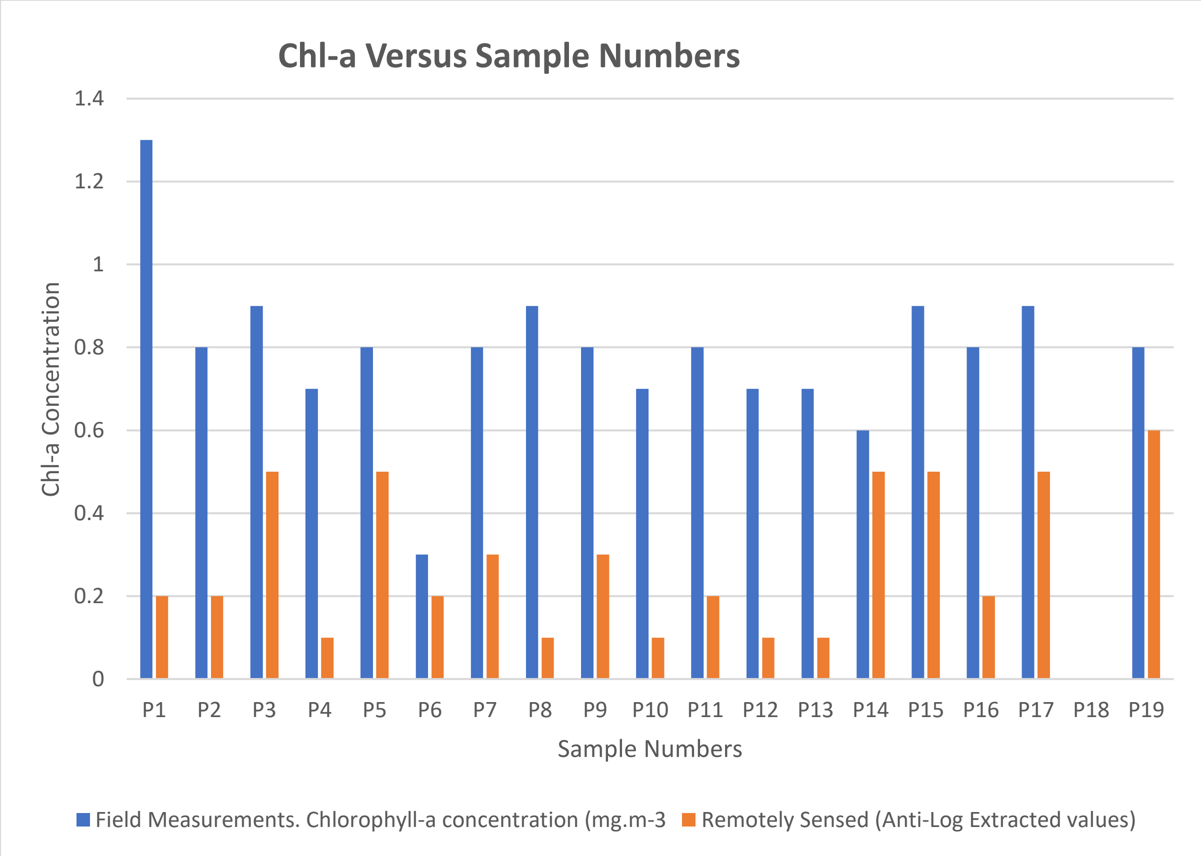

Figure 4. 21: Showing concentration of Chlorophyll-a for field measurements and remotely sensed data for Nandoni dam

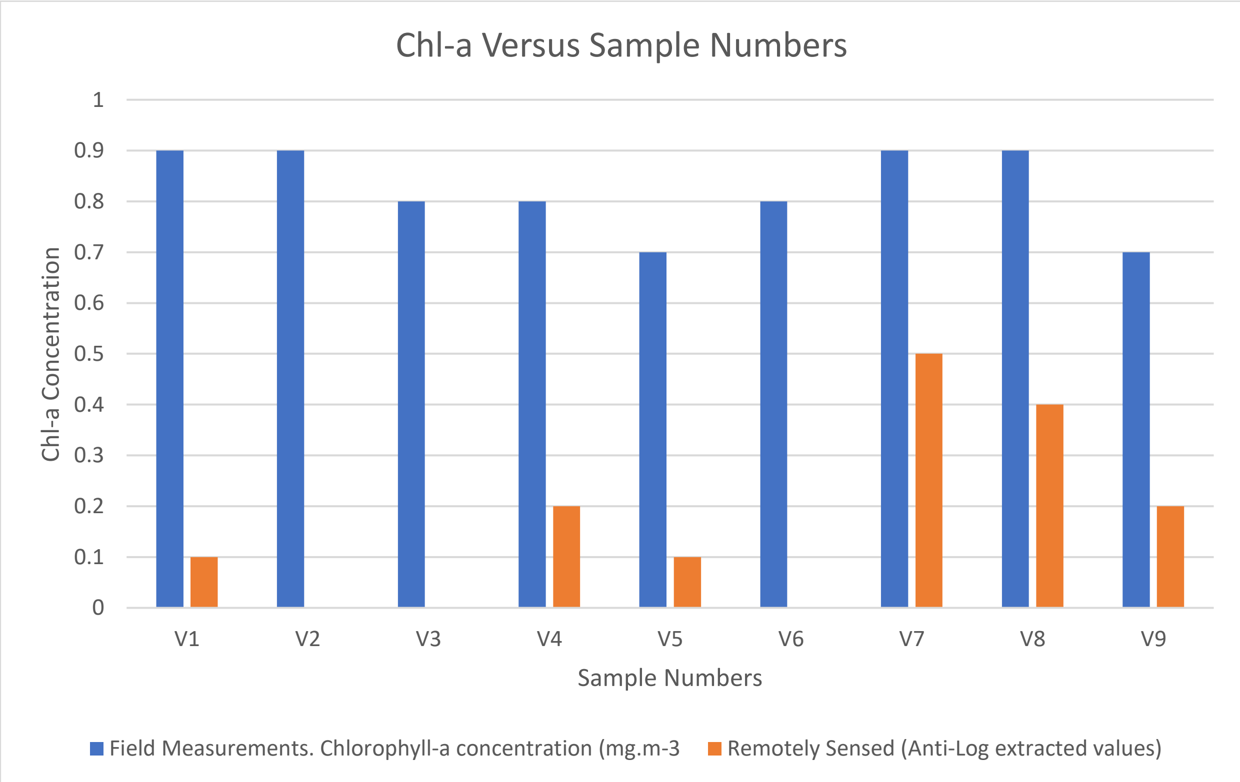

Figure 4. 22: Showing concentration of Chlorophyll-a for field measurements and remotely sensed data for Vondo dam

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the derived and measured total chlorophyll-a concentrations, Nandoni, Vondo and Albasini dams are considered to have low concentrations of chlorophyll-*a*. The algorithm employed in the images to derive chlorophyll-*a* worked successfully on the Landsat OLI images. It can be concluded that Landsat OLI is suitable for real time monitoring of harmful algal blooms in water bodies and can accurately map areas where cyanobacterial blooms are abundant. This was also attested by the Kappa coefficient value which determines the level of agreements between two or more data sets. 80 percent of K values were very high from 70% to 89% which shows high level of agreement of correlation values of field chlorophyll-a concentration and satellite remotely sensed variables.

From the findings of this study, it can be concluded that this study achieved the outlined objectives and successfully addressed the problems faced by fish farmers. On this study, the use of banana peels powder at concentration of 6mM, K was suitable for inhibition of growth of cyanobacterial blooms in fish ponds and safe for fish. The results also showed the effective inhibition of cyanobacteria with the use of Potassium Sulphate (K_2SO_4) stock material. From the results, the banana peels have proved to have high concentration of potassium as attested by XRF results, the concentration of K_2SO_4 and Banana peels was found to be 31.697 and 44.988w/w respectively. The experimental results revealed that the optimal conditions for inhibition of growth of cyanobacteria in pond water is 7 days, was 6 Mm K concentration. All physiochemical parameters in this study, temperature, pH, TDS, EC, turbidity and dissolved solids were suitable for fish growth and survival.

The one-way ANOVA statistical approach was used in this study and has outlined a pure significant values of Banana peel powder and Potassium Sulphate with the $p = 0.6$. This was also observed as positive because both treatment materials showed great inhibition ability during the experimental period. On the other hand, the ANOVA analysis showed the control samples to be having insignificant values of P, where the Banana and control, K_2SO_4 and control were showing very different values of absorbance from day 1 of experiment to the last day.

Based on one-way ANOVA statistical analysis, the results showed $p = 0.04$, where there is a significance difference between banana peel powder and control. Thus, banana peel powder was able to inhibit the growth of cyanobacteria. Secondly, the one-way ANOVA statistical analysis showed $p = 0.03$, where there is a significance difference between potassium sulphate fertiliser and control. Thus, potassium sulphate was able to inhibit the growth of cyanobacteria. Banana peel powder was a better inhibitor in comparison with potassium sulphate fertiliser.

5.2 Recommendations

Based on the findings of this study, the use of banana peels powder to inhibit the growth of algal blooms in fish ponds is highly recommended. Banana is considered effective for inhibition, harvested for free and with no detrimental effects to fish and other aquatic organisms. Furthermore, banana does not affect the water quality in the fish ponds. The possible use of the two treatments (banana and potassium Sulphate) in this study needs to be further investigated at much concentration and at wider time interval (in Months). It is recommended that water in the fish ponds should be changed regularly, this may also assist in reducing cyanobacterial blooms which were present before. Lastly, physicochemical parameters should also be monitored since water quality affects the production of fish and influence the growth of algae.

References

Adeleye, A. S., Conway, J. R., Garner, K., Huang, Y., Su, Y., & Keller, A. A. (2016). Engineered nanomaterials for water treatment and remediation: costs, benefits, and applicability. Chemical Engineering Journal, 286, 640-662.

Berold, R. (2005). Aquaculture gets a second choice in South Africa: aquaculture. Water Wheel, 4(3) 12-15.

Botes, L., Thompson, G., & Louw, R. (2006). Benchmarking Survey of the South African Aquaculture (Marine & Freshwater) sector. Aquaculture institute of South Africa.

Buditama, G., Damayanti, A., & Pin, T. G. (2017). Identifying Distribution of Chlorophyll-a Concentration Using Landsat 8 OLI on Marine Waters Area of Cirebon. In IOP Conference Series: Earth and Environmental Science (Vol. 98, No. 1, p. 012040). IOP Publishing.

Carmichael, W. W., & Boyer, G. L. (2016). Health impacts from cyanobacteria harmful algae blooms: Implications for the North American Great Lakes. Harmful Algae, 54, 194-212.

Camps-Valls, G., Gómez-Chova, L., Muñoz-Marí, J., Vila-Francés, J., Amorós-López, J., & Calpe-Maravilla, J. (2006). Retrieval of oceanic chlorophyll concentration with relevance vector machines. Remote Sensing of Environment, 105(1), 23-33.

Cristina, S., D'Alimonte, D., Goela, P. C., Kajiyama, T., Icely, J., Moore, G., & Newton, A. (2016). Standard and Regional Bio-Optical Algorithms for Chlorophyll $ a $ Estimates in the Atlantic off the Southwestern Iberian Peninsula. IEEE Geoscience and Remote Sensing Letters, 13(6), 757-761.

Department of Agriculture, Forest and Fisheries (DAFF) (2011). Aquaculture annual report 2011 South Africa.

Department of Agriculture, Forest and Fisheries (DAFF) (2013). National Aquaculture policy framework for South Africa. Republic of South Africa.

Department of Water Affairs and Forestry (DWAF), (2003) Sustainable Utilization Plan for the Nandoni Dam in the Thohoyandou District of the Limpopo Province; Department of Water Affairs and Forestry/Van Riet and Louw Landscape Architects: Pretoria, South Africa.

Department of Agriculture, Forestry & Fisheries (DAFF), (2012). A profile of the South African Aquaculture Market value Chain, 2012. http://www.nda.agric.za/docs/AMCP/Aquacult2012.pdf (date accessed 22/05/2016)

Devi, L., & Ohno, M. (2015). Effects of BACE1 haploinsufficiency on APP processing and Aβ concentrations in male and female 5XFAD Alzheimer mice at different disease stages. Neuroscience, 307, 128-137.

Dawood, M. A., Koshio, S., Ishikawa, M., & Yokoyama, S. (2015). Effects of partial substitution of fish meal by soybean meal with or without heat-killed Lactobacillus plantarum (LP20) on growth performance, digestibility, and immune response of amberjack, Seriola dumerili juveniles. BioMed research international, 2015.

Dube, T. (2012). Primary productivity of intertidal mudflats in the Wadden Sea: a remote sensing method. [Msc Thesis] University of Twente Faculty of Geo-Information and Earth Observation (ITC).

Dube, T., Gumindoga, W., & Chawira, M. (2014). Detection of land cover changes around Lake Mutirikwi, Zimbabwe, based on traditional remote sensing image classification techniques. African Journal of Aquatic Science, 39(1), 89-95.

Edokpayi, J. N., Odiyo, J. O., & Olasoji, S. O. (2014). Assessment of Heavy Metal Contamination of Dzindi River in Limpopo Province, South Africa. International Journal of Natural Sciences Research, 2(10), 185-194.

Edokpayi, J. N., Machaba, H. I., Ogombe, H. S., & Odiyo, J. O. (2016). Evaluation of Contamination of Soil by Trace Metals from Dairy Wastewater in Limpopo Province, South Africa. Der Pharma Chemica, 2016, 8 (7):16-24.

Fan, J., Ho, L., Hobson, P., & Brookes, J. (2013). Evaluating the effectiveness of copper sulphate, chlorine, potassium permanganate, hydrogen peroxide and ozone on cyanobacterial cell integrity. Water research, 47(14), 5153-5164.

Fan, J., Hobson, P., Ho, L., Daly, R., & Brookes, J. (2014). The effects of various control and water treatment processes on the membrane integrity and toxin fate of cyanobacteria. Journal of hazardous materials, 264, 313-322.

Space FAO, (2014). The state of the world fisheries and aquaculture, 2014. http://www.fao.org/3/a-i3720e.pdf(date accessed 22/05/2016)

Gammal, M.A.M.I.E.L, (2008). Potassium fertilizer inhibits the growth of cyanobacteria (Microcystis aeruginosa) in fishpond. 8th International Symposium on Tilapia in Aquaculture-2008. Limnology Department, Central Lab for Aquaculture Research, Abbassa Abou Hamad, Sharkia, Egypt.

Giardino, P. P., Karnnike, K., Masina, I,. Raidal, M & Strumia, A (2014). The universal Higgs fit. Journal of High Energy Physics. Springer Berlin Heidelberg

Hansen, C., Swain, N., Munson, K., Adjei, Z., Williams, G. P., & Miller, W. (2013). Development of sub-seasonal remote sensing chlorophyll-a detection models. American Journal of Plant Sciences, 4(12), 21.

Hansen, C.H., Williams, G.P. & Adjei, Z. (2015). Long-Term Application of Remote Sensing Chlorophyll Detection Models: Jordanelle Reservoir Case Study. Natural Resources, 6, 123-129.

Huang, Y., Chen, X., Li, P., Chen, G., Peng, L., & Pan, L. (2018). Pressurized Microcystis can help to remove nitrate from eutrophic water. Bioresource technology, 248, 140-145.

Hunter, P. D., Matthews, M. W., Kutser, T., & Tyler, A. N. (2016). Remote sensing of cyanobacterial blooms in inland, coastal, and ocean Waters. Handbook of Cyanobacterial Monitoring and Cyanotoxin Analysis, 89-99.

Hooker, S. B., Esaias, W. E., Feldman, G. C., Gregg, W. W., & McClain, C. R. (1992). An overview of SeaWiFS and ocean color. NASA tech. memo, NASA Goddard Space Flight Center, Greenbelt, Maryland. 104566(1), 24.

Jensen, J.R. (2007). Remote Sensing of the Environment: An Earth Resource Perspective (2nd edition) Upper Saddle River, NJ: Pearson Prentice Hall.

Keremah, R., Davies, O., & Abezi, I. (2014). Physico-chemical analysis of fish pond water in freshwater areas of Bayelsa State, Nigeria. Greener Journal of Biological Sciences, 4(2), 033-038.

Koçer, M. A. T., & Sevgili, H. (2014). Parameters selection for water quality index in the assessment of the environmental impacts of land-based trout farms. Ecological Indicators, 36, 672-681.

Koker, L., Akcaalan, R., Oguz, A., Gaygusuz, O., Gurevin, C., Kose, C. A., & Albay, M. (2017). Distribution of toxic cyanobacteria and cyanotoxins in Turkish waterbodies. J. Environ. Prot. Ecol., 18, 425-432.

Krüger, G. H. J., & Eloff, J. N. (1977). The influence of light intensity on the growth of different Microcystis isolates. Journal of the Limnological Society of southern Africa, 3(1), 21-25.

Kutser, T., Metsamaa, L., Strömbeck, N., & Vahtmäe, E. (2006). Monitoring cyanobacterial blooms by satellite remote sensing. Estuarine, Coastal and Shelf Science, 67(1), 303-312.

Kutser, T. (2009). Passive optical remote sensing of cyanobacteria and other intense phytoplankton blooms in coastal and inland waters. International Journal of Remote Sensing, 30:17, 4401-4425.

Lawton, L.A., & Robertson, P.K.J. (1999). Physico-chemical treatment methods for the removal of microcystins (cyanobacterial hepatotoxins) from potable waters. School of Applied Sciences, The Robert Gordon University, St Andrew Street, Aberdeen, UK. Chemical Society Reviews, 28, 217–224.

Matthews, M. W., Bernard, S., & Winter, K. (2010). Remote sensing of cyanobacteria-dominant algal blooms and water quality parameters in Zeekoevlei, a small hypertrophic lake, using MERIS. Remote Sensing of Environment, 114(9), 2070-2087.

Matthews, M. W., & Bernard, S. (2015). Eutrophication and cyanobacteria in South Africa's standing water bodies: A view from space. South African journal of science, 111(5-6), 1-8.

McClain, C.R., Esaias, W.E., Barnes, W., Guenther, B., Endres, D., Hooker, S.B., Mitchell, G. & Barnes, R. (1992). SeaWiFS Calibration and Validation Plan. NASA Tech Memo. 104566, 3.

McClain, C.R., Cleave, M.L., Feldman, G.C., Gregg, W.W., Hooker, S.B. and Kuring, N. (1998). Science quality SeaWiFS data for global biosphere research. Sea Technology Reprint. 10-16.

Meler, J., Ostrowska, M., Ficek, D., & Zdun, A. (2017). Light absorption by phytoplankton in the southern Baltic and Pomeranian lakes: mathematical expressions for remote sensing applications. Oceanologia, 59(3), 195-212.

Milenković, S. M., Zvezdanović, J. B., Anđelković, T. D., & Marković, D. Z. (2012). The identification of chlorophyll and its derivatives in the pigment mixtures: HPLC-chromatography, visible and mass spectroscopy studies. Adv Technol, 1(1), 16-24.

Mostert, T. H., Bredenkamp, G. J., Klopper, H. L., Verwey, C., Mostert, R. E., & Hahn, N. (2008). Major vegetation types of the Soutpansberg conservancy and the Blouberg nature reserve, South Africa. Koedoe, 50(1), 32-48.

Mouw, C. B., Greb, S., Aurin, D., DiGiacomo, P. M., Lee, Z., Twardowski, M., ... & Moses, W. (2015). Aquatic color radiometry remote sensing of coastal and inland waters: Challenges and recommendations for future satellite missions. Remote sensing of environment, (160), 15-30.

Munni, M., Fardus, Z., Mia, M., & Afrin, R. (2015). Assessment of Pond Water Quality for Fish Culture: A Case Study of Santosh Region in Tangail, Bangladesh. Journal of Environmental Science and Natural Resources ,6(2),157-162.

Ndungu, J., Monger, B. C., Augustijn, D. C., Hulscher, S. J., Kitaka, N., & Mathooko, J. M. (2013). Evaluation of spatio-temporal variations in chlorophyll-a in Lake Naivasha, Kenya: remote-sensing approach. International journal of remote sensing, 34(22), 8142-8155.

Odiyo, J. O., Phangisa, J. I., & Makungo, R. (2012). Rainfall–runoff modelling for estimating Latonyanda River flow contributions to Luvuvhu River downstream of Albasini Dam. Physics and Chemistry of the Earth, Parts A/B/C, 50, 5-13.

O'Reilly, J. E., Maritorena, S., Mitchell, B. G., Siegel, D. A., Carder, K. L., Garver, S. A., & McClain, C. (1998). Ocean color chlorophyll algorithms for SeaWiFS. Journal of Geophysical Research: Oceans, 103(C11), 24937-24953.

Paerl, H. W., & Otten, T. G. (2013). Harmful cyanobacterial blooms: causes, consequences, and controls. Microbial ecology, 65(4), 995-1010.

Paerl, H. W., Gardner, W. S., Havens, K. E., Joyner, A. R., McCarthy, M. J., Newell, S. E., & Scott, J. T. (2016). Mitigating cyanobacterial harmful algal blooms in aquatic ecosystems impacted by climate change and anthropogenic nutrients. Harmful Algae, (54), 213-222.

Pouria, S., de Andrade, A., Barbosa, J., Cavalcanti, R. L., Barreto, V. T. S., Ward, C. J., & Codd, G. A. (1998). Fatal microcystin intoxication in haemodialysis unit in Caruaru, Brazil. The Lancet, 352(9121), 21-26.

Pretorius, M., Huggett, J., & Gibbons, M. (2016). Summer and winter differences in zooplankton biomass, distribution and size composition in the KwaZulu-Natal Bight, South Africa. African Journal of Marine Science, 38(sup1), S155-S168

Raber, G. T., Jensen, J. R., Hodgson, M. E., Tullis, J. A., Davis, B. A., & Berglund, J. (2007). Impact of LiDAR nominal post-spacing on DEM accuracy and flood zone delineation. Photogrammetric engineering & remote sensing, 73(7), 793-804.

Rashid, I. & Romshoo, S.A. (2013). Impact of anthropogenic activities on water quality of Lidder River in Kashmir Himalayas. Journal of Environmental Monitoring and Assessment. 185: 4705. https://doi.org/10.1007/s10661-012-2898-0

Rocchio, L. (2010). About Landsat. National Aeronautics and Space Administration, 25. https://www.nasa.gov/pdf/315067main_fy10_nasa.pdf (date accessed 23/06/2016).

Rouhani, Q. A. & Britz, P.J. (2004). Contribution of aquaculture to rural livelihoods in South Africa: a baseline study. Pretoria: Water Research Commission.

Schrader, K. K., Tucker, C. S., Brown, T. W., Torrans, E. L., & Whitis, G. N. (2016). Comparison of phytoplankton communities in catfish split-pond aquaculture systems with conventional ponds. North American journal of aquaculture, 78(4), 384-39

Shen, L., Xu, H., & Guo, X. (2012). Satellite remote sensing of harmful algal blooms (HABs) and a potential synthesized framework. Sensors, 12(6), 7778-7803.

Stumpf, R. P., Davis, T. W., Wynne, T. T., Graham, J. L., Loftin, K. A., Johengen, T. H., & Burtner, A. (2016). Challenges for mapping cyanotoxin patterns from remote sensing of cyanobacteria. Harmful Algae, 54, 160-173.

Tang, J.-y., Dai, Y.-x., Li, Y.-m., Qin, J.-g., & Wang, Y. (2016). Can Application of Commercial Microbial Products Improve Fish Growth and Water Quality in Freshwater Polyculture? North American journal of aquaculture, 78(2), 154-160.

Tebbs, E., Remedios, J., & Harper, D. (2013). Remote sensing of chlorophyll-a as a measure of cyanobacterial biomass in Lake Bogoria, a hypertrophic, saline–alkaline, flamingo lake, using Landsat ETM+. Remote Sensing of Environment, 135, 92-106

Trescott, A. (2012). Remote Sensing Models of Algal Blooms and Cyanobacteria in Lake Champlain. Environmental & Water Resources Engineering Masters Projects. University of Massachusetts Amherst. Paper 48.

United States Environmental Protection Agency (USEPA). (2012). Guideline for water reuse. National Risk Management Research Laboratory, Office of Research and Development, Cincinnati, Ohio.

United States Environmental Protection Agency (USEPA). (2012). Guideline for water reuse. National Risk Management Research Laboratory, Office of Research and Development, Cincinnati, Ohio.

Vilmi, A., Karjalainen, S.M., & Landeiro, V.L. (2015). Freshwater diatoms as environmental indicators: evaluating the effects of eutrophication using species morphology and biological indices. Journal of Environmental Monitoring and Assessment. (187), 243.

Water Quality Research Australia (WQRA). 2009. International guidance manual for the management of toxic cyanobacteria. Global water research coalition.

Winarso, G., & Ishizaka J (2017). Validation of cochlodinium polykrikoides red tide detection using seawifs-derived chlorophyll-a data with nfrdi red tide map in south east korean waters. International Journal of Remote Sensing and Earth Sciences, (14), 19 – 26.

Zi, J., Pan, X., MacIsaac, H. J., Yang, J., Xu, R., Chen, S., & Chang, X. *(*2018). Cyanobacteria blooms induce embryonic heart failure in an endangered fish species. Aquatic Toxicology, 194, 78-85.

Zimba, P. V., Khoo, L., Gaunt, P. S., Brittain, S., & Carmichael, W. W. (2001). Confirmation of catfish, Ictalurus punctatus (Rafinesque), mortality from Microcystis toxins. Journal of Fish Diseases, 24(1), 41-47.

Appendices

Appendix A: Showing Absorbance results for Banana, K_2SO_4 and Control during inhibition of Cyanobacteria for 6 days on the Spectrophotometer.

Days	Abs (A) at 750nm		
	K_2SO_4	Banana	Control
0	0.936	0.936	0.936
1	0.805	0.693	1.004
2	0.502	0.333	1.079
3	0.3	0.127	1.172
4	0.185	0.046	1.21
5	0.101	0.002	1.223
6	0.07	0	1.234
7	0.00	0.00	1.239

Appendix B: Showing Physicochemical characterisation of different treatment and control during experiment

Parameter	Banana treatment							K_2SO_4 treatment							Control						
	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
pH	8.3	7.8	7.9	8.2	8.2	7.4	7.7	8.1	7.5	7.9	8.0	7.7	8.0	8.2	7.1	7.9	7.2	7.9	7.4	7.4	7.7
EC (µs/cm)	82.7	76.5	78.7	67.0	86.4	84.4	78.8	87.9	84.9	83.7	80.8	85.5	82.9	81.0	59.9	65.7	71.9	63.1	69.9	77.5	70.0
TDS (mg/L)	63.5	63.0	65.8	67.6	62.3	68.2	61.0	69.7	67.7	65.9	69.0	69.0	61.7	67.0	64.8	53.6	59.9	61.6	59.2	54.9	52.6
Temperature (°C)	27.77	27.8	28.8	28.0	27.9	26.2	29.3	27.8	27.9	28.1	25.5	27.5	26.6	26.9	27.7	28.7	27.9	27.3	26.1	28.1	28.0
DO (mg/L)	6.4	6.4	6.5	6.8	6.9	6.9	7.1	6.0	6.1	6.3	6.6	6.6	6.7	6.8	5.3	5.9	6.1	6.8	7.3	8.2	8.4

Appendix C: Showing Chlorophyll-*a* results for different seasons during 2016, 2017 and 2018 for Tshifulanani fish pond

Seasons (Year)	Chlorophyll-*a* mg/m^{-3}	Turbidity (NTU)
Winter 2016	2.14	9.01
Summer 2016	2.32	10.86
Winter 2017	3.11	13.99
Summer 2017	3.13	14.59
Winter 2018	3.62	15.23
Summer 2018	4.01	15.96

Appendix D: Showing Chlorophyll-a results for different seasons during 2016, 2017 and 2018 for Lwamondo fish pond

Seasons (Year)	Chlorophyll-*a* mg/m^{-3}	Turbidity (NTU)
Winter 2016	0.65	8.89
Summer 2016	0.88	9.98
Winter 2017	1.22	13.64
Summer 2017	2.41	14.59
Winter 2018	2.98	15.02
Summer 2018	3.0	15.66

Appendix E: Showing ANOVA results between Potassium Sulphate and Banana Peel powder

Groups	*Count*	*Sum*	*Average*	*Variance*
K2SO4	8	2.899	0.362375	0.123561
Banana	8	2.137	0.267125	0.130662

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.03629	1	0.03629	0.285499	0.601502	4.60011
Within Groups	1.779563	14	0.127112			
Total	1.815853	15				

Appendix F: Showing ANOVA results between Banana Peel powder and Control

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Banana	8	2.137	0.267125	0.130662
Control	8	9.097	1.137125	0.013602

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.0276	1	3.0276	41.97281	0.04985	4.60011
Within Groups	1.009854	14	0.072132			
Total	4.037454	15				

Appendix G: Showing ANOVA results between Potassium Sulphate and Control

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
K2SO4	8	2.899	0.362375	0.123561
Control	8	9.097	1.137125	0.013602

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.40095	1	2.40095	35.00865	0.0376	4.60011
Within Groups	0.960143	14	0.068582			
Total	3.361093	15				