

**ASSESSING THE IMPACTS OF SMALL-HOLDER FARMING ACTIVITIES ON WETLAND
AREA IN NZHELELE AGRICULTURAL HUB IN THE VHEMBE DISTRICT, LIMPOPO
PROVINCE, SOUTH AFRICA**

By

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**A dissertation submitted in fulfilment of the requirements of Master of Environmental
Sciences degree.**

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DECLARATION

I, **Mapfumo Mulisa Norah**, hereby declare that this dissertation for the Masters in Environmental Sciences [MscEnv] degree submitted to the University of Venda has not been submitted previously for any degree at this or another university. It is original in design and execution, and all reference material contained therein has been duly acknowledged.

Signature



Date 29/06/2023

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DEDICATION

To my brother Mapfumo Tsireledzo and little sister Mapfumo Khumbudzo. I wish you to grow and follow in your big sister footsteps and achieve much more than what I have achieved.

ABSTRACT

Wetlands play a crucial role in supplying essential ecosystem products and services, yet they are threatened by several anthropogenic activities. Wetlands are at risk of crop production which depend on the reliability of water supply. The effects of farming on wetlands are a result of the exploitation of wetland resources and the extensive usage of fertilizers. Notwithstanding the alleged role that farming plays in the destruction and degradation of wetlands, wetland area fluctuations and anthropogenic impacts over time and across regions have not been adequately assessed. The aim of this case study research was to assess the impacts of small-holder farming activities on wetland area in Makhado Local Municipality, in Vhembe District of Limpopo Province. Data was collected through interviews and the main data collection tools were a questionnaire, Landsat 8 satellite and UAV images of 2014, 2018 and 2022. The participants of the study included a variety of individuals such as farmers, household heads, extension officer (Mulimisi) and of the community. The Statistical Package for Social Sciences (SPSS) software was used to analyze the survey data. Analysis of satellite imagery was done using Aeronautical Reconnaissance Coverage Geographic Information System (ArcGIS) (Version 10.1) and Earth Resources Data Analysis System ERDAS Imagine (version 2015) software packages. The results show that farming is the major activity within the wetland area over the years 2014 to 2022 which increased from 96 hectares to 181 hectares. Throughout the study period, there have been significant changes to the wetland region. The main contributory factors were the expansion of agriculture (cultivation), increased food demand due to population growth and local water deficit. There is insufficient assistance and mentoring provided by the government to the community and to small-holder farmers when it comes to land use reform and awareness building among villagers and farmers about the importance of wetlands. The results also show that 78.3% of the respondents are not aware that farming has impacts on wetland areas while 17.7% of the respondents are aware. Lack of knowledge has been identified as one of the major factors contributing to the environmental effects of land use change in the wetland area. This study suggested that to manage wetland resources properly, local small-holder farmers and the local community should both be targeted for awareness campaigns and initiatives.

Keywords: Farming, impacts, land use change, small-holder farming, Unmanned Aerial Vehicle (UAV), wetland,

ACRONYMS

ArcGIS	Aeronautical Reconnaissance Coverage Geographic Information System
HGM	Hydrogeomorphic
PES	Present Ecological State
QIGIS	Quantum Geographic Information System
RS	Remote Sensing
SPSS	Statistical Package for Social Sciences
UAV	Unmanned Aerial Vehicle
UHDC	University Higher Degrees Committee

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CHAPTER 1: ORIENTATION OF THE STUDY

1.1 Introduction

This study assesses the impacts of small-holder farming activities on wetland areas at Nzhelele Agricultural Hub in Makhado Local Municipality, Vhembe District in the Limpopo Province, South Africa. This section provides a brief background of the impact of small-holder farming on wetland areas and states the rationale, aim and objectives of the study.

1.2 Background of the study

The Ramsar Convention defined wetlands as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters" (Kingsford et al., 2016). Wetlands are sensitive and crucial systems in our environment, however, they are diminishing and degrading at an alarming rate (Mosase et al., 2019). Wetlands must be conserved not just to ensure the sustainability of our water supplies but also to ensure that nations abide by the national and international accords that support such conservation efforts. International, regional, and national laws and agreements pertaining to the preservation of water indicated that it is important to reserve water. The Ramsar Convention and the Convention on Biological Diversity (CBD) are both international agreements related to the conservation and sustainable use of ecosystems, but they have some important differences in their focus and scope. Wetlands are sensitive and crucial systems in our environment (Ottinger et al., 2013).

Since 1900, more than 50% of the world's wetlands have vanished, despite their significance and our dependence on them (Chaparro et al., 2019). Wetlands are important because they provide advantages that no other environment can offer. Some of the advantages include free natural resources for human use, free flood protection, free shoreline erosion prevention, free recreational and aesthetic opportunities. and free natural water quality enhancement. Wetlands have been shown to be valuable to humanity, yet their survival and capacity to deliver crucial ecological functions are in danger. Globally, wetland loss is assumed to be primarily caused by agriculture. It was estimated that by 1985, intensive agriculture would have drained between 56 and 65% of usable wetland in Europe and North America, 27 % in Asia, 6 % in South America, and 2% in Africa (De Klerk et al., 2016). Even though agriculture is directly responsible for wetland loss, population increase is also one of the primary underlying causes of wetland degradation. A growing population strains food and water supplies by converting undeveloped land to

communities and farms, increasing industrial and agricultural production, and building infrastructure. Wetland drainage is also influenced by urban and industrial growth, but this contribution is far less significant than that of agricultural conversion (Ottinger et al., 2013). Due to overuse of wetland features, services and products, which include wetlands that are rich in biodiversity, wetland quality is being degraded (Botham et al., 2015).

In the case of Africa, a large portion of the continent is arid or semi-arid, with inconsistent availability of fresh water. In some cases, for the entire population, the only source of water and grazing is mostly found in wetland areas. Wetlands in Africa are a vital source of nutrients and water. Locals in four wetlands in South Africa recognized 16 distinct products and services provided by wetlands (Rebelo et al., 2018). African subsistence and local farmers would suffer greatly if the continent's wetlands disappeared since goods and services would also be lost.

Factors that put extra strain on wetlands include population growth, rising poverty, and economic hardship, all of which could be made worse by drought, according to a study by (Tiner, 2016). The intricacy was increased by the fact that landowners do not equally profit from wetlands. While local communities bear the cost of conversion and the public benefit from the wetland, wetland conversion could result in higher revenues for private landowners (Rebelo et al., 2018). The loss of biodiversity is intimately related to the degradation of wetlands. The reduction of wetlands and biodiversity in Sub-Saharan Africa is attributed to several factors, including habitat destruction and fragmentation, desertification, the introduction of foreign species and the collecting and hunting of specific wild species (Yu et al., 2018).

An analysis of wetland inventories in Southern Africa allowed researchers to determine the amount of wetland resources in 10 of the region's countries. The Tugela Basin, where more than 90% of the basin's wetland resources have been depleted and the Mfolozi catchment, where 58% of the original wetland area has been destroyed, are the two regions in Natal for which loss numbers are provided (Nhamo, 2017).

In South Africa, as in the rest of the developing world, the population is growing quickly, and economic aspirations are rising. In addition to significant population expansion, changes in political power have sparked a push for quick development, further taxing our natural resources. The natural resources that are the foundation of our long-term development are regularly depleted as a result of these circumstances (Mosase et al., 2019). Estimates state that between 35 and 50% of South Africa's wetlands have disappeared (De Klerk et al., 2016). The primary causes are the establishment of foreign trees in wetlands, improperly controlled burning and grazing that

causes donga erosion, drainage of wetlands for crops and pastures, mining, pollution, and urban growth (Ottinger et al., 2013).

Wetland conservation in South Africa has not received much attention due to factors such a lack of knowledge about the number of wetlands, a lack of planning tools for their preservation and an inability to meet international commitments to wetland protection (Stagg et al., 2020). Many wetlands-related studies have been carried out abroad, particularly in the United States of America, and many of them do not apply to South African surroundings. Wetland loss is still mostly caused by conversion to agricultural use on a global scale (Ottinger et al., 2013).

In South Africa, grazing is the main purpose of agricultural land. Among the cash crops farmed in South Africa are maize, wheat, sugar cane, oats and sunflowers (Donetell et al., 2018). One of the most significant industries in the nation and one that generates income is agriculture. It has a tremendous impact on the entire economy because it affects secondary manufacturers and cities in addition to farmers (Stagg et al., 2020).

South Africa has advanced significantly in terms of its economy, society, and politics since 1994. With over a third of agricultural output exported, South Africa's economy, which includes agriculture, is participating more and more in international markets (Ottinger et al., 2013). It exports a lot of agricultural and food products, including sugar, wine, and fresh produce. South African agriculture, on the other hand, is immensely dualistic, with a huge number of subsistence farms controlled mostly by black farmers and a tiny number of commercial operations dominated by white farmers. The continuation of land reform, provision of adjustment support and development of trade are the most pressing issues facing agricultural policy (Botham et al., 2015).

Wetlands provide vital ecological services and activities that are beneficial to humans, including biodiversity preservation, climate adaptation and the provision of essential habitats, commodities and tourism resources (Tiner, 2016). Yet, major wetland loss has occurred globally as a result of intensive human activity and climate change. Serious ecological effects of such losses include floods, biodiversity loss, coastal erosion, water quality degradation and decreased carbon sequestration (Botham et al., 2015). Human efforts should therefore be made to address these wetland losses and their negative effects (Donetell et al., 2018).

Without wetlands, municipalities must spend more money purifying water for their residents, floods do more damage to nearby areas, hurricane storm surges can extend further inland, animals are uprooted or go extinct, and livelihoods and the food supply are disrupted, according

to (Chaparro et al., 2019). Human activity has polluted many wetlands, particularly those near urban areas. Waterways frequently carry pollutants from earlier operations, such as sewage facilities, chemical factories, refineries, and industry, as well as nutrients, heavy metals, pesticides, and toxins. The consequences of point source contamination have diminished in Queensland's wetlands as a result of more environmental awareness (Ottinger et al., 2013).

A developing issue is non-point source pollution caused by widespread land-use techniques like grazing, urbanization, agriculture, and land removal (Chaparro et al., 2019). Wetlands have been eutrophicated because of altered land use due to increased nutrients entering them through sedimentation, fertilizer runoff and organic waste. These nutrients promote the growth of aquatic plants and phytoplankton. Due to the marsh's high amounts of organic detritus, there could be severe deoxygenation, which would lower water quality and cause a significant loss of aquatic species (Tiner, 2016).

Broad-scale land-use practices like urbanization, agriculture, and grazing cause non-point source pollution, which is an increasing issue (Chaparro et al., 2019). Because of changes in land use, wetlands have grown increasingly eutrophic because of the increased nutrients brought in by sedimentation, fertilizer runoff and organic wastes. These nutrients promote the growth of phytoplankton and aquatic plants. High levels of organic trash in the marsh may cause severe deoxygenation, lowering water quality and causing a significant decline in aquatic species (Tiner, 2016).

Distance sensing according to Uzarski et al., (2017) offers crucial data that can be used as a wetlands mitigation strategy to characterize and monitor wetland states, conditions and functioning. Maps of flooded areas and information on the scale of dynamic wetland areas can both be obtained from Earth observation (EO) satellites, according to (Donetell et al., 2018). Moreover, they can be used to map different habitat types, vegetation communities and ecosystem services. They can also be used to track changes in water quality, cyanobacteria blooms, trophic status and terrestrial carbon inputs (Mosase et al., 2019). Since the introduction of the Landsat sensor series in 1972, the number of satellites and aerial sensors available to inform and advance knowledge about wetlands has multiplied tremendously. Understanding changing ecosystems like wetlands requires periodic data from EO satellites. Scientists are already processing significantly more data from EO satellites than they can handle because this plethora of data is practically untapped. Given this context, the goal of this study is to evaluate how small-holder farming operations in the Limpopo province's Vhembe District's Nzhelele agricultural center are affecting the wetland there.

1.3 Conceptual Framework

A conceptual framework is a depiction of an anticipated relationship between variables shown in writing or visual form. In this study, the following conceptual framework was adopted to discuss the reasons for wetland degradation and loss, the impact of wetland degradation and loss and responses to wetlands ecosystems.

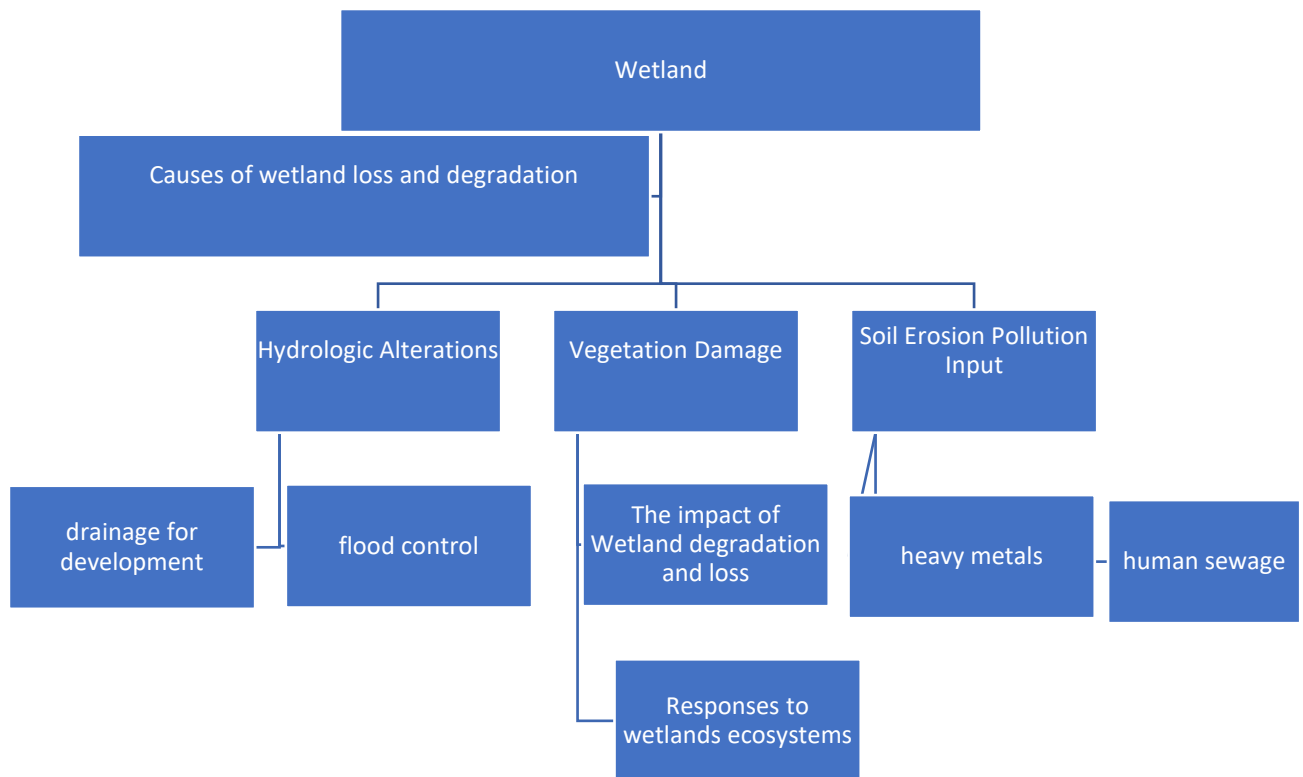


Figure 1: The conceptual framework of the study on the effects of farming on wetlands

1.4 Problem Statement

The loss of wetlands is a major concern nationally, provincially, and locally. Wetlands are the most endangered ecosystems in South Africa, according to the study by Chaparro et al. (2019), with 48% of its wetland ecosystem types being critically endangered, 12% endangered, 5% vulnerable, and 35% least threatened. To address disparities and underdevelopment, the South African government has implemented numerous reforms to national policies and laws, such as the National Water Act, over the last ten years. Wetlands are not always specifically addressed despite the South African government's policy and deeds (Pence & Hardcastle, 2016). In terms of wetland legislation, there are overlaps and gaps and shared responsibilities amongst ministries

result in inadequate implementation. The reality is that many people rely on natural ecosystems such as wetlands for water and food, Clear standards on the sustainable use of wetlands in farming are crucial for the preservation of wetlands in South Africa. Many research projects have been carried out to look into the impact of agriculture on the biophysical and socioeconomic environment. Donetell et al. (2018) looked at the effects of agriculture on soil quality, water quality and consumption, human health, and air quality. As far as the researcher is aware, the Nzhelele Agricultural Hub contains no data on how farming affects wetland regions. This is made worse by a dearth in knowledge regarding the effects that small-holder farmers' agricultural practices have on the wetlands in the research area.

According to the study by Pheti & Gumbo (2019) , the primary land uses that were destroying the wetlands regions were road construction, animal grazing and crop cultivation. This study assessed the influence of land use change on the wetland at Makhitha Village, Limpopo Province, South Africa. According to the study by Neswiswi (2019) , which examined the effects of land use activities on wetlands along the Dzindi River, a number of wetlands there are subjected to various human activities such as substantial maize crop farming, sand and clay mining, as well as afforestation.

1.5 Aim of the study

This study aimed to assess the impacts of small-holder farming activities on wetlands in the Nzhelele Agricultural Hub in the Vhembe District, Limpopo Province.

1.6 Specific research objectives

- a) Map small-holder farming activities in wetland areas at Nzhelele Agricultural Hub using Unmanned Aerial Vehicle (UAV) and Landsat 8,
- b) Analyse the effects of present and past land use change dynamics on Phadzima wetland soils.
- c) Determine how local farmers perceive the effects of farming on wetland areas at the Nzhelele Agricultural Hub.

1.7 Hypotheses

The study hypothesizes that the main cause of the change in land use and cover in the Phadzima wetland environment is agriculture. This means that the conversion of land within the wetland area for agricultural purposes is believed to be the most significant factor contributing to changes

in the vegetation and overall land cover in that area. The study also suggests that ArcGIS, remote sensing, and sociological surveys can be utilized as tools to characterize and identify changes in land cover and use in the Phadzima wetland environment. Each of these methods provides valuable information and contributes to a comprehensive understanding of the dynamics and drivers of land use and cover change.

1.8 Significance of the study

Wetland ecosystem integrity must be maintained by minimizing factors that have a negative impact on how well the wetlands function to continue providing its benefits and services. The Ramsar Convention on Wetlands and the objectives of the Environmental Management Act 107 of 1998 are all targeted for the ongoing loss of wetlands, which is a constant barrier to the full achievement of the Millennium Developmental Goals (MDGs). To manage wetlands ecosystems effectively, it is necessary to continuously analyze their state as well as the factors affecting their capacity to produce products and services. The lack of knowledge on the location and quantity of wetlands affects decisions for sustainable environmental management and policies. The management and conservation of wetlands must therefore consider research on past and present changes in wetland size and quality.

Several rural populations in the study area depend on wetland services to support their way of life. For instance, they depend on agricultural output, natural resources, livestock grazing during the dry season, water availability, fisheries and other aesthetic and cultural qualities. Carbon dioxide is removed from the atmosphere by carbon sinks, which gather and store some carbon-containing chemical molecules. To inform the management and maintenance of wetlands, research that evaluate the effects of small-holder farming operations on the wetland in the Nzhelele agricultural hub in Vhembe District, Limpopo province, is essential.

1.9 Operational definitions of key terms

Small-holder farming

Smallholdings are farms that provide food for a single family and usually mix subsistence farming with cash cropping. As a nation gets richer, smallholdings become less self-sufficient, but they continue to be essential for promoting the rural way of life (Ottinger et al., 2013).

Impacts

The term impact refer to strong effect that something has on a situation or person (Donetell et al., 2018). In this study, Unsustainable land use activities, such as deforestation and other destructive practices, can have a range of negative impacts on the environment, ecosystems, and communities. It is crucial to address unsustainable land use practices through sustainable land management, reforestation efforts, improved agricultural practices, and the promotion of conservation and restoration initiatives.

Wetland

An area in which water is present at or near the soil surface or the soil is covered by water throughout the year or for varied lengths of time especially during the growing season (Ottinger et al., 2013).

Remote sensing

Remote sensing is a technique that acquires information about a phenomenon or object without getting physical contact with it, as opposed to in situ or on-site observation. The term is often used in studying the Earth and other planets (Ali et al., 2016).

Geographic Information System (GIS)

A type of database that combines software tools for managing, analyzing, and displaying data with spatial information (Ottinger et al., 2013).

Land use

The term "land use" refers to how a person utilizes land. Agriculture, housing, industry, mining and leisure are few examples of the economic and cultural activities that utilizes land (Bouasria et al., 2020).

Land cover

Land cover is the physical material that covers the Earth's surface. Examples of land covers include water, bare ground, trees, asphalt and grass. Vegetation is the closest modern equivalent of the term "earth cover," as used by ecologist Frederick Edward Clements (Bouasria et al., 2020).

Social survey

The term "social survey" is commonly used to refer to research that is conducted using survey software or on social media and is based on the systematic gathering of sample data via questionnaires or interviews. The data gathered is then numerically examined (Botham et al., 2015).

1.10. Outline of the dissertation

The dissertation is composed of 5 chapters:

Chapter 1: The background of the study, it introduces the study, states the problem, aim and objectives, hypotheses and explains why the study is important. It also provides the operational definitions of the terms commonly used throughout the dissertation.

Chapter 2: The extant literature about land use/cover issues is reviewed in this chapter.

Chapter 3: Explains the research's topic area, methodology, sampling size, data gathering tools, and data processing techniques.

Chapter 4: Discusses and summarize the key study findings, their interpretation, and implications for the research topics and body of knowledge.

Chapter 5: Describe how the results relate to the study's goal and provide conclusions and suggestions if needed.

CHAPTER 2: LITERATURE REVIEW

The literature review in this study focused on the Farming practices in wetlands, Rate of wetland degradation and loss attributed to farming activities, Impact of farming practices on wetland ecological conditions. The researcher consulted books and journal articles on the research topic. In South Africa, 65% of households depend on subsistence farming in wetlands to cover their food needs, (Motiang, 2017); (Pheti & Gumbo, 2019). Overuse of wetland products, services results in the destruction of wetlands, which are extremely rich in biodiversity (Neswiswi, 2019).

2.1 Farming practices in wetlands

Farming practices in wetlands have been a subject of scientific research and discussions due to their potential impacts on wetland ecosystems. Here is a summary of some key findings from the literature on farming practices in wetlands:

2.1.1 Wetland drainage for agriculture

The conversion of wetlands for agricultural purposes involves the drainage of waterlogged areas. Research has highlighted that wetland drainage for farming can lead to changes in hydrological regimes, including altered water flow patterns, reduced water storage capacity, and increased vulnerability to flooding. These changes can negatively impact wetland vegetation, wildlife habitat, and overall ecosystem functioning.

2.1.2 Nutrient management

According to the by Motiang (2017); Pheti & Gumbo (2019) agricultural activities in wetlands often involve the use of fertilizers to enhance crop production. However, as per Neswiswi (2019) improper nutrient management can result in excessive nutrient runoff into wetland systems. The study by De Klerk et al. (2016) has shown that nutrient enrichment from agricultural runoff can cause eutrophication in wetlands, leading to harmful algal blooms, oxygen depletion, and disruptions in the balance of the ecosystem.

2.1.3 Pesticide use

Chaparro et al., (2019) indicated that Pesticides are commonly used in agriculture to control pests and diseases. However, Mosase et al. (2019) posits that the of pesticides application in wetlands can have adverse effects on non-target organisms, including wetland plants, invertebrates, and

aquatic organisms. Research study by Yu et al. (2018) suggests that pesticide runoff from agricultural fields can contaminate wetland water bodies and harm sensitive species.

2.1.4 Wetland restoration and sustainable agriculture

There is growing recognition of the need to integrate wetland conservation and restoration with sustainable agricultural practices. Research study by Nicol et al. (2015) has explored strategies such as wetland buffer zones, agroforestry, and rotational grazing, which can help mitigate the negative impacts of agriculture on wetlands. These approaches aim to minimize nutrient runoff, reduce soil erosion, and preserve wetland functions while maintaining agricultural productivity.

2.1.5 Wetland-friendly farming practices

Several studies Yu et al. (2018); Kingsford et al. (2016) have focused on identifying and promoting wetland-friendly farming practices that balance agricultural productivity with wetland conservation. These practices include precision agriculture techniques, optimal fertilizer and pesticide application, water management strategies, and the establishment of buffer zones. Such practices aim to minimize negative impacts on wetlands while supporting sustainable agricultural production.

2.1.6 Socioeconomic considerations

Alongside ecological factors, the socioeconomic dimensions of farming practices in wetlands are also important. The study by Ali, et al. (2016) has examined the socio-economic drivers of wetland agriculture, including land tenure systems, market demands, and policy frameworks. Understanding the social and economic aspects can help identify opportunities and challenges for promoting sustainable farming practices in wetlands.

2.2 Rate of wetland degradation and loss attributed to farming activities.

The rate of wetland degradation and loss attributed to farming activities in South Africa has been a matter of concern. Wetlands in South Africa are vital ecosystems that provide various ecological services, including water purification, flood control, and habitat for numerous plant and animal species.

The precise rate of wetland degradation and loss attributed to farming activities in South Africa may vary across different regions and depend on local factors. Specific studies and data on the

rate of wetland loss due to agriculture in South Africa may provide more accurate and up-to-date information.

Agricultural activities, especially in the form of irrigation and land conversion, have contributed to the degradation and loss of wetlands in the country. Some of the key factors that have led to wetland degradation and loss in South Africa include:

2.2.1 Drainage and land conversion

Wetlands have been drained and converted into agricultural fields to expand farming areas. This practice directly results in the loss of wetland ecosystems and the services they provide. Ali et al. (2016) Drainage and land conversion are significant drivers of wetland degradation worldwide, including in South Africa. When wetlands are drained, their natural hydrological processes are disrupted, leading to the degradation and loss of wetland ecosystems. Kingsford et al. (2016) Land conversion refers to the transformation of wetlands into other land uses, such as agriculture or urban development, resulting in the direct loss of wetland habitats.

In the context of farming activities in South Africa, Mosase et al. (2019) indicate that drainage and land conversion have been identified as key factors contributing to wetland degradation. The study by Tiner, (2016) Wetlands are often drained to reclaim the land for agriculture, particularly for crop cultivation or livestock grazing. Sharma et al. (2015), indicated that the drainage of wetlands alters the natural water flow patterns, reduces water retention capacity, and diminishes the ability of wetlands to absorb and filter water.

Yu et al. (2018) indicated that the conversion of wetlands into agricultural fields involves clearing vegetation, levelling land, and altering the soil structure. Furthermore, Mosase et al. (2019) indicate that this process disrupts the ecological balance of wetland ecosystems and can result in the loss of unique wetland plant and animal species, as well as the services provided by wetlands.

2.2.2 Irrigation practices

Ambani (2014) indicated that inefficient or poorly managed irrigation practices can lead to waterlogging, salinization, and erosion, affecting the hydrological balance and health of wetlands. Nicol et al. (2015) posits that irrigation practices can contribute to wetland degradation when they are not properly managed or when they result in water-related impacts on wetland ecosystems.

In the context of farming activities, irrigation is often employed to supply water to crops in areas where rainfall is insufficient or unreliable.

2.2.3 Agrochemical use

Excessive use of fertilizers and pesticides in agricultural practices can contaminate wetland water systems, affecting the quality of water and the biodiversity that depends on it Kingsford et al., (2016). Mahdianpari et al. (2020) indicated that agrochemical use, including the excessive application of fertilizers and pesticides, can contribute to wetland degradation. While agrochemicals are used to enhance agricultural productivity, their improper use can have adverse effects on wetland ecosystems.

Colefax et al. (2018) indicated that agrochemicals, such as fertilizers and pesticides, can enter wetland ecosystems through runoff or leaching. When these chemicals reach wetlands, they can contaminate water bodies, affecting water quality and the health of aquatic organisms. Excessive nutrient runoff from fertilizers can lead to eutrophication, causing algal blooms and oxygen depletion, which harm wetland plants and animals.

Siebert & Teizer, (2014) indicated that agrochemicals can directly impact wetland species, pesticides, for instance, can be toxic to aquatic organisms, including fish, amphibians, and invertebrates that rely on wetlands for habitat. The loss of these species can disrupt the ecological balance and reduce overall biodiversity in wetland ecosystems. Furthermore, De Klerk et al. (2016) agrochemicals can alter the nutrient cycles and other essential ecosystem processes within wetlands. Excessive fertilizers can result in imbalances, affecting nutrient availability and microbial activity. Such disruptions can impact the structure and functioning of wetland ecosystems, including the decomposition of organic matter and nutrient recycling.

2.2.4 Overgrazing

Overgrazing, which refers to the excessive grazing of livestock in a particular area, can contribute to wetland degradation (Pheti & Gumbo, 2019). Additionally, Neswiswi (2019) posits that when wetland areas are subjected to overgrazing, it can have negative impacts on the health and functioning of wetland ecosystems. Livestock grazing in wetland areas can lead to trampling and soil compaction, altering wetland hydrology and vegetation composition.

Livestock trampling in wetland areas can lead to soil compaction, which reduces the soil's ability to absorb and retain water. De Klerk et al. (2016) indicated that compacted soils have reduced

infiltration rates, resulting in increased surface runoff and decreased water availability for wetland vegetation. This can disrupt the hydrological balance of wetlands and affect their overall health.

Ambani (2014), indicated that overgrazing can result in the removal or destruction of wetland vegetation. Livestock may consume plant species faster than they can naturally regenerate, leading to the loss of vegetation cover. Ottinger et al., (2013) explained that vegetation plays a vital role in stabilizing wetland soils, preventing erosion, and providing habitat and food sources for wetland species. Loss of vegetation can alter the structure and composition of wetland ecosystems and reduce biodiversity.

2.3 Impact of farming practices on wetland ecological conditions

Farming practices can have significant impacts on wetland ecological conditions. Depending on the specific practices employed, these impacts can be either positive or negative. Here are some common farming practices and their potential effects on wetland ecological conditions:

2.3.1 Land conversion and habitat loss

Land conversion and habitat loss due to farming practices have significant impacts on wetland ecological conditions. Tiner (2016) indicated that when wetlands are converted into agricultural fields, it results in the direct loss of wetland habitats, leading to a range of ecological consequences. This loss can lead to a decline in wetland-dependent species and the disruption of ecological processes that rely on wetland ecosystems.

According to the study by Moses et al. (2019) wetlands are known for their high biodiversity and provide habitat for a wide variety of plant and animal species, including many rare and threatened species. Sharma et al. (2015) articulated that land conversion for agriculture eliminates or fragments wetland habitats, leading to the loss of specialized wetland species and reduced overall biodiversity in the area.

According to the study by Botham et al. (2015) wetland ecosystems perform essential ecological processes such as water filtration, nutrient cycling, and flood mitigation. Land conversion disrupts these processes, impacting the overall health and functioning of wetland ecosystems. Rebelo et al. (2018) indicated that the loss of wetland habitats can lead to changes in hydrology, nutrient dynamics, and species interactions, altering the natural balance and functioning of the ecosystem.

2.3.2 Drainage and hydrological alteration

Farming activities often involve drainage systems to remove excess water from fields. According to Nhamo (2017), the excessive drainage can lead to water level fluctuations in wetlands, causing changes in water availability and hydrological patterns. These fluctuations can negatively impact wetland plants and animals adapted to specific water regimes, disrupting their life cycles, breeding patterns, and overall distribution.

The study by Mosase et al. (2019) informed that agricultural activities often involve drainage to remove excess water from fields. However, excessive drainage can alter the natural hydrological regime of wetlands, leading to water level fluctuations, reduced water retention capacity, and changes in wetland plant and animal communities.

Stagg et al. (2020) Wetlands naturally act as water storage and retention systems, helping to regulate water flow and maintain water availability during dry periods. Donetell et al. (2018) indicated that when wetlands are drained for farming purposes, their water retention capacity is diminished. This can result in reduced water availability downstream, affecting the functioning of both wetland and downstream ecosystems, including water quality, sediment deposition, and habitat availability.

Stagg et al. (2020) indicated that alteration of hydrological conditions through drainage can lead to changes in wetland vegetation composition. Chaparro et al. (2019) indicated that some plant species may decline due to changes in water table levels, while others that are more tolerant of drier conditions may invade the area. Such shifts in vegetation can impact the structure of the wetland ecosystem, alter nutrient cycling, and affect the habitat suitability for wetland-dependent species.

2.3.4 Agrochemical use and water quality.

The use of fertilizers and pesticides in farming can contribute to water pollution in wetlands. Tiner (2016) informed that agrochemical runoff from agricultural fields can introduce excess nutrients, such as nitrogen and phosphorus, into wetland water systems, leading to eutrophication. According to Chaparro et al. (2019), pesticides can also have toxic effects on wetland organisms, impacting the biodiversity and ecological balance of the wetland.

Tiner (2016) indicated that excessive or improper use of fertilizers in farming can lead to the runoff of nutrients, such as nitrogen and phosphorus, into nearby water bodies, including wetlands. This

nutrient runoff can result in eutrophication, where the increased nutrient levels stimulate the growth of algae and aquatic plants. Uzarski et al., (2017) indicated that eutrophication can negatively affect wetland ecosystems by causing algal blooms, oxygen depletion, and shifts in species composition, leading to the degradation of water quality and potential harm to wetland species.

According to the study by Donetell et.al. (2018) agrochemicals can have indirect effects on wetland ecosystems by affecting the abundance and diversity of aquatic organisms. Pesticides, for example, can harm beneficial insects that serve as food sources for wetland-dependent species such as birds and fish. The reduction in prey availability can have cascading effects on the entire food web within the wetland, impacting the populations of higher trophic level species.

2.3.5 Soil erosion and sedimentation

According to the study by Pheti & Gumbo, (2019) study, Unsustainable farming practices, such as improper soil management and excessive tillage, can contribute to soil erosion. Mosase et al., 2019 indicated that Eroded sediments can be transported into wetlands, leading to increased sedimentation. Excessive sedimentation can degrade wetland habitats, reduce water clarity, and alter the composition of wetland vegetation. The loss of topsoil can reduce soil fertility, affect the productivity of wetland vegetation, and disrupt the nutrient cycling processes within the wetland ecosystem.

Soil erosion from agricultural fields can result in the deposition of eroded sediments in wetland water bodies, such as streams, rivers, or ponds (Murungweni et al., 2020). De Klerk et al. (2016) indicated that excessive sedimentation can negatively impact wetland habitats by reducing water clarity, decreasing light penetration, and smothering benthic organisms and aquatic plants. Sedimentation can also alter the physical structure of wetland habitats, reducing habitat complexity and altering the availability of microhabitats for aquatic species (Chaparro et al., 2019).

De Klerk et al. (2016) indicated that Soil erosion and sedimentation can lead to the loss or degradation of wetland habitats, including wetland banks, floodplains, and channels. Moreover, Chaparro et al. (2019) indicated that changes in habitat structure and composition can result in the loss of specialized wetland species, reduce biodiversity, and disrupt ecological interactions within the wetland ecosystem. Species that rely on specific habitats or require clean, sediment-free water may be particularly vulnerable to the impacts of sedimentation.

According to the study by Pheti & Gumbo (2019) study, Farming practices such as ploughing, tilling, and removal of vegetation can increase soil erosion in wetlands. Soil erosion contributes to sedimentation, where eroded soil particles are transported and deposited in wetland water bodies. This sedimentation can negatively impact wetland habitats, water quality, and the overall structure and function of the ecosystem.

2.3.6 Nutrient cycling and productivity

Donetell et al. (2018) looked Farming activities often involve the application of fertilizers to enhance crop growth and productivity. When used appropriately and in accordance with recommended practices, fertilizers can provide essential nutrients to crops and indirectly influence nutrient availability in wetland ecosystems. According to a study by Neswiswi (2019), nutrient inputs from agricultural runoff can potentially increase nutrient availability in wetlands, stimulating plant growth and productivity.

Motiang (2017) indicated that sediments transported through erosion may contain excess nutrients, including phosphorus and nitrogen, which can contribute to nutrient imbalances within wetland ecosystems. Neswiswi (2019) indicated that elevated nutrient levels can lead to eutrophication, promote excessive algae and plant growth, and disrupt the natural balance of the wetland ecosystem. This can impact water quality, oxygen levels, and the overall health of wetland species.

According to the study by De Klerk et al. (2016), Properly managed farming practices, such as sustainable nutrient management and crop rotation, can positively influence wetland nutrient cycling and productivity. Controlled nutrient inputs can enhance wetland plant growth and provide additional food sources for wetland-dependent species.

According to the study by Ambani(2014), Farming activities often involve the application of fertilizers to enhance crop growth and productivity. When used appropriately and in accordance with recommended practices, fertilizers can provide essential nutrients to crops and indirectly influence nutrient availability in wetland ecosystems. Ottinger et al. (2013) indicated that Nutrient inputs from agricultural runoff can potentially increase nutrient availability in wetlands, stimulating plant growth and productivity.

2.3.7 Conservation measures

Conservation measures play a crucial role in mitigating the negative impacts of farming practices on wetland ecological conditions. By implementing effective conservation measures, it is possible to minimize the adverse effects and promote the sustainability of wetland ecosystems.

Kumar, (2014) indicated that implementing conservation practices within farming operations, such as creating buffer zones, establishing riparian vegetation, and preserving wetland areas, can help mitigate negative impacts on wetland ecological conditions. These measures can protect wetland habitats, maintain water quality, and support biodiversity conservation.

According to a study by Chaparro et al., (2019) raising awareness among farmers, landowners, and local communities about the importance of wetland conservation and the impacts of farming practices is essential. Providing education and outreach programs that highlight the value of wetlands, the benefits of sustainable farming practices, and the availability of support for conservation efforts can encourage voluntary adoption of conservation measures.

2.4 Integration of remote sensing in wetland ecological conditions assessment

Remote sensing plays a valuable role in assessing wetland ecological conditions by providing detailed information about wetland characteristics, vegetation dynamics, hydrological patterns, and land cover changes.

Mahdianpari et al. (2020) indicated that remote sensing enables the identification, mapping, and classification of wetland areas at various spatial scales. Bouasria et al. (2020) articulated that satellite imagery, such as those from sensors like Landsat and Sentinel, can be used to distinguish wetland vegetation types based on their spectral signatures. This information helps in delineating wetland boundaries, assessing wetland extent, and understanding wetland distribution patterns.

Bouasria et al. (2020) indicated that remote sensing allows for the monitoring of vegetation dynamics and changes in wetland ecosystems over time. By analyzing satellite imagery captured at different time points, changes in vegetation cover, species composition, and productivity can be detected. This information is crucial for assessing wetland health, identifying ecological shifts, and understanding the impacts of farming practices or other stressors on wetland vegetation.

Remote sensing has been widely used in wetland mapping due to its ability to provide timely, accurate, and consistent information about wetlands over large areas (Mahdianpari et al., 2020).

Remote sensing enables repeated coverage, which is beneficial when collecting data on dynamic issues like water, agricultural fields, and other comparable locations. Bouasria et al. (2020) articulated that remote sensing allows for the quick collection of data at different scales and resolutions. By enabling the coverage of very large areas, remote sensing enables regional surveys on a variety of themes and the identification of very large features. For gathering data on dynamic themes like water, agricultural fields and other similar areas, remote sensing's ability to provide repeating coverage is quite useful. With the help of remote sensing, data may be easily collected at different scales and resolutions (Ali et al., 2016). Remote sensing's ability to cover very wide areas allows for regional surveys on various topics and the detection of very huge features.

Wetlands have long been used for agricultural purposes. Among other essential ecosystem services, they provide things like food, clean water, soil preservation, and nutrient cycling. Yet sometimes people ignore the value of these services. Some wetlands have been extensively drained and restored for agricultural use, but understanding of the vital links between agriculture and healthy wetlands is only just beginning to emerge (Kingsford et al., 2016).

2.4.1 Application of Remote Sensing in wetland mapping,

Chaparro et al. (2019) Remote Sensing helps identify and classify different types of wetlands based on their spectral signatures. Furthermore, Kingsford et al. (2016) indicated that Remote Sensing enables the delineation of wetland boundaries and the mapping of wetland types such as marshes, swamps, and bogs, as well as allowing for the assessment of temporal changes in wetland extent and condition, by comparing satellite imagery from different time periods, it is possible to monitor wetland loss, gain, and alteration due to factors such as urbanization, agriculture, or climate change. Ali et al. (2016)

Posits that Remote sensing data aids in studying wetland hydrology by monitoring water levels, inundation patterns, and water quality parameters, and that it helps in understanding wetland dynamics, water storage capacity, and the impact of hydrological changes on wetland ecosystems. Bouasria et al. (2020) indicated that Remote sensing assists in mapping and monitoring wetland habitats, including vegetation types and distributions, provides valuable information for assessing species diversity, habitat suitability, and the conservation status of wetland-dependent fauna and flora.

2.4.1.1 The challenges

Wetland ecosystems exhibit complex spectral characteristics due to the presence of different vegetation types, water, and sediment. Kingsford et al. (2016) indicated that distinguishing between various wetland components accurately can be challenging, requiring sophisticated data processing techniques and multi-sensor fusion. Additionally, Ali et al. (2016) indicated that wetland mapping often requires high spatial resolution imagery to capture fine-scale wetland features and small wetland patches. However, Bouasria et al. (2020) indicated that acquiring such imagery can be expensive, and the availability of high-resolution data may be limited, especially in remote or inaccessible areas because of the atmospheric effects, such as scattering and absorption of electromagnetic radiation, can distort the information received by remote sensing sensors. Furthermore, Bouasria et al. (2020) indicated that corrections for atmospheric interference are necessary to ensure accurate wetland mapping results. Wetland dynamics necessitates regular and frequent acquisition of satellite imagery to capture seasonal changes and short-term variations. Kingsford et al. (2016) indicated that limited revisit times of satellites and cloud cover can hinder the availability of suitable imagery for wetland monitoring.

2.4.1.2 The opportunities

Bouasria et al. (2020) indicated that technological advancements in remote sensing, including the development of hyperspectral and LiDAR sensors, offer improved capabilities for wetland mapping. Ali et al. (2016) indicated that hyperspectral data can provide detailed spectral information, enabling better discrimination of wetland components, while LiDAR data facilitates accurate elevation modeling and 3D mapping. Integrating data from multiple sensors and sources, such as optical and radar data or combining remote sensing with field observations, can enhance wetland mapping accuracy. Furthermore, Ali et al. (2016) indicated fusion techniques allow for the integration of complementary information and better characterization of wetland properties. Siebert & Teizer (2014) indicated that the application of machine learning and artificial intelligence techniques can improve wetland mapping and classification. Colefax et al. (2018) indicated that these methods enable automated feature extraction, classification, and change detection, enhancing the efficiency and accuracy of wetland mapping processes. Increasing availability of open satellite data, such as those provided by programs like Landsat and Sentinel, offers opportunities for wider access to free or low-cost imagery for wetland mapping. These initiatives facilitate research, monitoring, and conservation efforts related to wetland ecosystems.

2.4.2 Advantages of Landsat 8

The Operational Land Imager (OLI) and Thermal Infrared are two of the 11 spectral bands on the Landsat 8 satellite. With spatial resolutions of 30 meters (visible, NIR, and SWIR), 100 meters (thermal), and 15 meters, these two sensors offer seasonal coverage of the continents of the world (panchromatic). The OLI gathers data in the visible, panchromatic, and short-wave infrared spectral regions, whereas TIRS only records images in the thermal range (Kumar, 2014).

In addition to other things, the photographs from the Landsat 8 could be used to monitor things like changes in sea ice, road and city construction, deforestation, and agricultural activities. The calibration of Landsat 8's instruments is the following stage in completing its mission (Bouasria et al., 2020). The spacecraft's settings must be modified for it to precisely measure the light that its sensors detect. Having the devices see landscapes with comparatively consistent light characteristics is one of the ways researchers will reference check the instruments. Scientists are optimistic that once the satellite starts performing normal tasks, it will enable people to better understand the rapid changes occurring on the earth's surface (Ozelkan et al., 2016).

2.4.3 Advantages of Unmanned Aerial Vehicle (UAV)

Unmanned Aerial Vehicles (UAVs), also known as drones, have emerged as a valuable tool for wetland mapping and landscape feature analysis. UAVs can capture high-resolution imagery and data, providing detailed information on wetland and landscape features such as vegetation cover, hydrology, and soil characteristics. Unmanned aerial vehicles (UAVs), also referred to as drones, are aircrafts that can be flown autonomously or remotely under the control of automation or pre-programmed software (Siebert & Teizer, 2014). Many different industries and organizations, including the military, the government, the private sector, and recreational consumers, are utilizing this technology. Because of developments in control technology, most drones can be deployed and controlled with only a moderate amount of experience. Because to this and the generally low price of most models, drones are becoming more affordable for a variety of operators. UAVs can also travel further than manned aircraft. As they can fly in more directions and at a lower altitude, they can more easily explore previously inaccessible places (Colefax et al., 2018).

2.5 Chapter Summary

This chapter explored the impact of farming practices on wetland ecological conditions, focusing on various aspects such as wetland degradation, habitat loss, hydrological alterations, water quality, soil erosion, sedimentation, nutrient cycling, and productivity. The chapter emphasized

the need for conservation measures and the integration of remote sensing in wetland ecological condition assessments. The degradation of wetlands due to farming activities is a significant concern, with practices such as drainage, land conversion, overgrazing, and agrochemical use contributing to habitat loss and ecological disruption. The chapter highlighted the importance of understanding the impacts of farming practices on wetland ecosystems, particularly in relation to soil erosion and sedimentation. Excessive soil erosion and sedimentation can result in the loss of topsoil, alteration of habitat structure, nutrient imbalances, and impacts on wetland-dependent species. The chapter also discussed the impacts of farming practices on nutrient cycling and productivity in wetlands. Furthermore, the chapter emphasizes the importance of integrating remote sensing in wetland ecological condition assessments. Remote sensing enables wetland mapping, vegetation monitoring, hydrological analysis, land cover change detection, habitat assessment, and water quality monitoring. The chapter underscored the need for conservation measures and the integration of remote sensing in assessing and mitigating the impacts of farming practices on wetland ecological conditions. By implementing sustainable land management practices, adopting appropriate water management strategies, promoting conservation measures, and utilizing remote sensing techniques, it is possible to protect and preserve the ecological integrity of wetland ecosystems, ensuring their long-term sustainability.

CHAPTER 3: RESEARCH METHODOLOGY

3.1. Introduction

This chapter outlines the research methodology utilized in the study. It starts by explaining the research design adopted for the study, describing the study area, sampling procedure and the techniques used to carry out the study using remote sensing, Arc-GIS, and social survey approach.

3.2 Description of the study area

The wetland region in Phadzima village, a major agricultural hub in Limpopo, is the subject of the study. Phadzima wetland has long been a valuable resource for the neighborhood and continues to be crucial to local farming in the twenty-first century. Phadzima village is located on common land that is under the jurisdiction of the Mphephu Tribal Government (22°95'49.38"S, 30°19'92.10"E). The local chief oversees the management of state-owned land. The settlement is in the Makhado Local Municipality Vhembe District Municipality of the Limpopo Province of South Africa's (Figure. 2). Phadzima Village has a total area of 1.85 km² (Census, 2011). The settlement has 2,684 inhabitants, who are split among 617 (332.78 per) houses. There are 1 481 (54.86%) more women than men in the entire population of 2,684 people (Census, 2011). Formal employment (primarily in the public sector), self-employment, subsistence farming, raising livestock and resource collection are the main sources of income. Government handouts (mostly pensions and children's' grants) and home-based microbusinesses like tailoring, car washes and welding are other significant sources. In the village, subsistence farming, livestock raising, and habitation are the main land uses.

The research was conducted in the Phadzima wetland area due to farming activities prevalent in the area. The Phadzima wetland is situated along Mudzinga River, a tributary of the massive Munzhedzi River. The climate of the catchment area is characterized by hot, humid summers and cool, dry winters (Stagg et al., 2020). Rainfall is primarily seasonal, falling between October and March 95% of the time (Murungweni et al., 2020). Figure 3.1 shows the location of Phadzima Village.

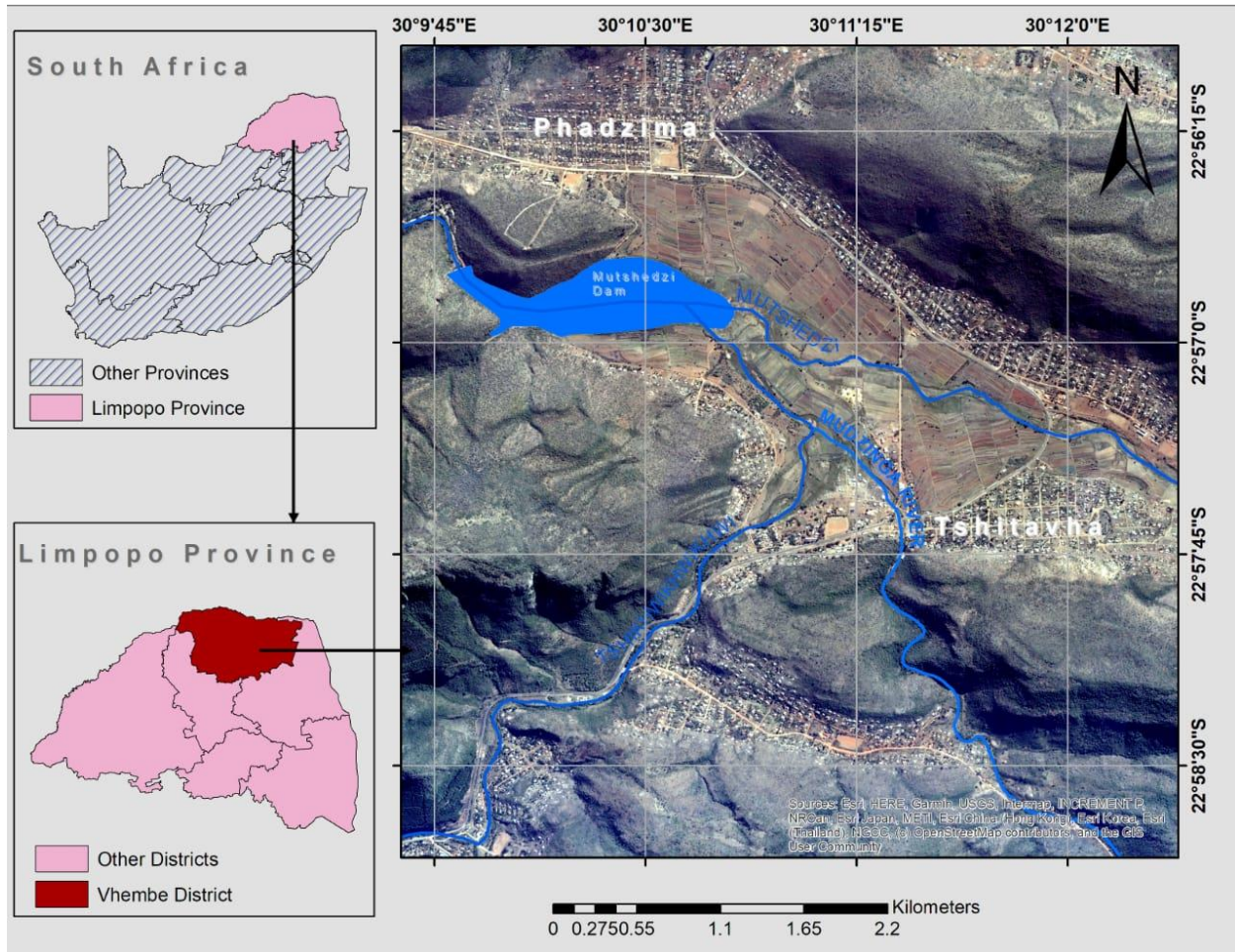


Figure 2: Location of Phadzima wetland area, in Nzhelele, Makhado Local Municipality, Vhembe District, Limpopo Province, South Africa

3.3 Research Design

The research design is the process and specifications for data collection and analysis that ensures that the data are pertinent to the study's goals (Creswell, 2017). This study employed a descriptive research methodology where both qualitative and quantitative techniques were utilized. The statistical correlation between several factors that affect wetlands and data gathered through remote sensing using ArcGIS was analyzed using a quantitative technique, while the opinions and attitudes of the participants were examined using a qualitative technique. This case study aimed to assess the impacts of small-holder farming activities on wetlands in the Vhembe District, Limpopo Province's Nzhelele agricultural hub. Different data from diverse sources was gathered using remote sensing/GIS (satellite images, maps), sociological survey and other methods (questionnaires, field survey, observations, and key informants) to effectively address

research objectives. To detect changes in land use/cover over time, the data on wetland was analyzed utilizing a variety of techniques and technologies, including Arc GIS (version 10.1) and ERDAS (version 2015).

3.4 Research methodology

The study utilized a mixed methods approach with a combination of qualitative and quantitative methods since the two approaches are complementary (see Figure 3). Several data collection techniques were used to improve the reliability of the research findings and improve confidence level. The quantitative approach was utilized to describe various outcomes regarding the impacts of land use change in the research region. Different techniques were used for triangulation purposes to effectively collect, analyze, compare, and interpret both qualitative and quantitative data.

In "mixed methods" research, both quantitative and qualitative data are gathered and analysed for a single study (Creswell, 2017). In this instance, facts were combined, incorporated, and evaluated to offer accurate results. The mixed methods approach was used in this study because it reduces various forms of bias, accurately captures the essence of the topic under investigation and enhances validity of the research findings. The procedure followed is shown in Figure 3.

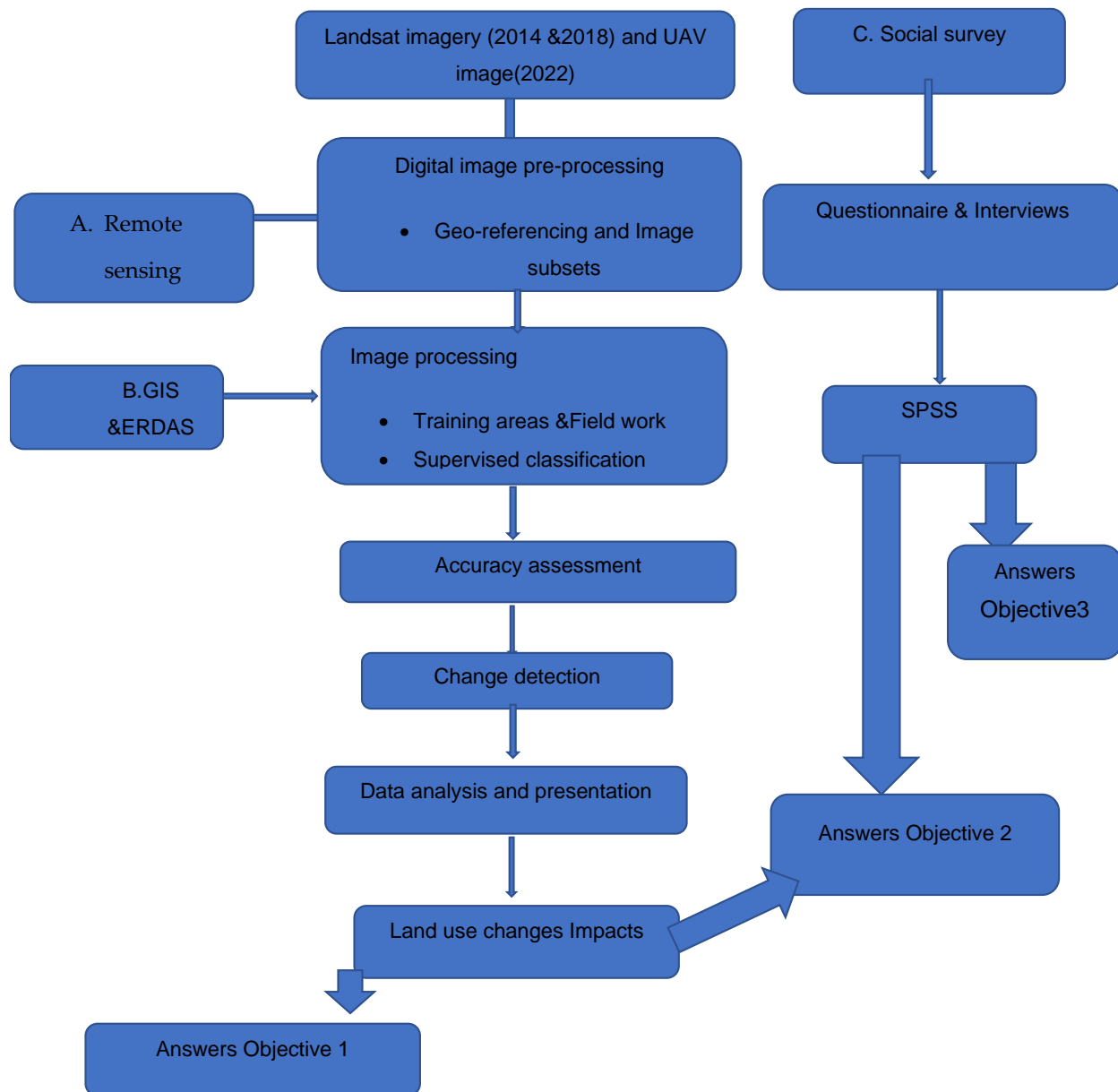


Figure 3: Research methodology

3.4.1 Sampling method and sample size

Random sampling technique was used to select the respondents. Random sampling is one of the probability sampling techniques where everyone has an equal chance of being chosen. Households in the area who had witnessed land transformation were targeted because they had a history of farming in the area, and they had seen how the use and cover of the land have changed through time. In this research, out of 85 farmers, 42 were interviewed according to whom was found available during the interview and 20 community members who reside adjacent to the

wetland area were sampled which represents the population of the study area. This means that not all the farmers were part of the sampling for the purpose of reducing time and cost.

To learn more about the wetland in the research area, a sample of satellite images from various years was chosen. Tables 1 and 2 show the sample techniques utilized for satellite data and social survey data, respectively.

Table 1. *Satellite data sampling methods*

Research objective	Sources of information	Sampling methods	Data analysis
To map small-holder farming activities in wetlands area at Nzhelele agricultural hub;	UAV Image Field observation	Supervised image classification Maps and satellite images	Satellite Landsat 8 and UAV imagery using GIS and ERDAS software from 2014,2018 and 2022
Analyse the impact of the present and past land use change dynamics on wetland;	UAV Image Google earth Field observation	Supervised image classification Maps and satellite images Random sampling	Satellite Landsat 8, UAV and Google earth imagery using GIS and Content analysis. This was achieved by measuring the mean changes in area size over time

Table 2: *Social survey sampling method*

Research objective	Sources of information	Sampling Methods	Sampling size and data analysis
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To determine how locals perceive the effects of farming on wetlands areas at the Nzhelele agricultural hub	(Questionnaires/interview guide) Key Informants Field Observation	Random sampling	Content analysis: data collected from 62 participants was grouped according to similarities
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3.4.2 Satellite data collection

In this study satellite data, which was used is called Landsat 8 and UAV. The Landsat 8 satellite has 11 spectral bands and consists of two sensors-Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). These two sensors provide seasonal coverage of the global landmass at a spatial resolution of 30 meters (visible, NIR, SWIR); 100 meters (thermal); and 15 meters (panchromatic). Data for the visible, panchromatic band, short wave infrared spectral bands are collected by the OLI while TIRS collects images in the thermal region (Kumar & Gantayat, 2015). The UAV called DJI Mavic 2 Pro drone was used in this study, DJI Mavic 2 Pro is a versatile and capable drone that is widely used by both professional photographers/videographers and hobbyists due to its excellent camera quality, portability, and intelligent flight capabilities. The DJI Mavic 2 Pro drone is capable of capturing photos with a resolution of up to 20 megapixels. It features a 1-inch CMOS sensor that allows for high-resolution still images. It has a maximum height of 120 meters. A total of two (2) Landsat 8 OLI images were acquired for the period 2014-2018 from the United States Geological Surveys (USGS)'s Earth Explorer website (<https://earthexplorer.usgs.gov/>). Search results were limited to specified days and month, satellite images of 1st of November to 31st of November 2014 and 2018 were downloaded and less than 25% cloud cover. On 30 November 2022, a UAV imagery and videos of the study area for the year 2022 was captured at a maximum height of 120 meters at a certain distance of 138 with a 360 view to contain a better diameter view. Images from 2014, 2018 and 2022 were geo-rectified and they were free of inaccuracies caused by changes in the satellite's orbit and platform attitude. Images were chosen because they were readily available.

Images from the year 2014, 2018 and 2022 were georeferenced and transferred to the ERDAS image version 2015 during digital image pre-processing. The base image was taken from Google Earth. A minimum of 25 ground control points was used. road junction and dams were used as ground control points. In this study, UTM projection was used as it is commonly used and

preferred projected coordinate system. To guarantee that coverage overlaps spatially, the three imageries were reduced using the ERDAS envision program 2015 and recognizable landmarks in each image were found. Subsets of sample points were created using the geostatistical analyzer in ERDAS for training and accuracy evaluation.

The technique of classifying pixels in an image involves treating each pixel as a separate unit made up of values from several spectral bands. This work employed the supervised image classification (Pheti & Gumbo, 2019) method, which is loosely described as the method of classifying unknown-identity pixels using samples of known individuals. ERDAS envision was used to create signatures for all three photos. For creating signatures from which the classification would be determined, polygons were built around the points for the creation of signatures from which the classification would be made. Classes were made for 4 signatures using the signature editor for ERDAS and this procedure was applied to all three photos. The wetlands and surrounding area were covered by the developed signature classes.

The created signature classes were as follows:

- Water:** All open bodies of water including streams and wetland
- Vegetation:** All vegetation which occurred naturally in the area either dry or not
- Barren/ bare land:** All area that is not cultivated including degraded area and roads.
- Cultivation:** All plants/vegetation planted by humans in the area.

The maximum likelihood approach for supervised classification is used in this work. By assuming that the data for each band are normally distributed, the maximum-likelihood technique calculates the likelihood that a given pixel belongs to a particular class (Sisodia et al., 2014). Red, blue, and green (RGB) band combinations, according to Kumar (2014), are useful since they display images in conventional color composites and allow for visual interpretation for land use and vegetation mapping, both of which are frequently utilized in tropical settings. Red, blue, and green bands were displayed in this study's UAV photos for visual interpretation of land use (band 1,2, and 3). Images from the years 2014 and 2018 were blended with a UAV image from the year 2022 to precisely depict the wetland conditions. After categorization, the accuracy of the final images required to be evaluated. Accuracy assessment compares two sources of information, one based on analysis of remote sensing data, and another based on different sources of information

assumed to be accurate (Congalton & Green, 2019). In this study the error matrix accuracy method was adapted.

A random stratified sampling method using geostatistical analyst in ERDAS was used. In order to increase accuracy, the classified imagery of 2014, 2018 and 2022 was overlaid with Landsat 8 and UAV image for the purpose of accuracy assessment of the study area. It was crucial to compare the classified images with known points in order to achieve verification and accuracy of land cover for the classified imagery.

3.4.3 Social survey data collection

The most common use of the phrase "social survey" is to describe research that is based on the systematic gathering of sample data through interviews or questionnaires and is carried out utilizing survey software or a social media platform (Creswell, 2017). The data is then quantitatively examined after the information has been acquired. Field observations and the delivery of questionnaires to various residences, small-holder farmers and other significant informants comprised the primary data gathering methods in the study area. The sociological survey was conducted to enhance the data from remote sensing. The sociological survey was crucial to achieving the research objective of learning how residents view the effects of farming on wetlands areas.

Questionnaires

To collect the required data that would answer the research questions of the study, a questionnaire was used. The questions were clearly worded so that the respondents could understand better. The questionnaire was semi-structured. The key justification for using a semi-structured questionnaire with open ended questions was to allow respondents to express their own opinions. A research assistant helped in delivering questionnaires to the selected households. The questionnaire was handed in hard copies, to those who can understand and be able to write the were given opportunity to do so those who need assistance with interpreting language and writing the were helped by a researcher and research assistant.

Key informants

The key informants who received the questionnaires included farmers, members of the farming committee and the Extension officer (Mulimisi). To reduce bias, a variety of key informants were identified. The researcher carefully selected the key informants keeping in mind their expertise in

comprehending, providing insight on the issues and providing proposals for remedies regarding the influence of land use change on the wetland environment. Tshivenda was used during the interviews to those who cannot understand English, and the interviews were in-person as hard copies while the questionnaire was interpreted by the primary researcher.

Field survey/observation

The main goal of the field survey was to observe what was going on to corroborate research findings from the other data collection methods. Activities such as mapping small-holder farming activities in the wetlands area, analysing the impact of recent and historical land use change dynamics on wetland, and ascertaining how the locals felt about how farming was affecting the area were conducted. A field survey was an important way of gauging the impact of the shift in land use. The training zone for supervised classification needed to be determined and field survey and observation were required to confirm that the classification map accurately reflected the actual field scenario. For accuracy testing, GPS coordinates points from various locations were gathered and field-verified together with their matching cover classifications.

3.5 Data analysis methods

Remote sensing and GIS

Using the software packages Arc-GIS (version 10.1) and ERDAS (2015), imagery change analysis was performed. This was accomplished through the development of signature classes, accuracy evaluation and image pre-processing. Tables, frequencies tables, graphs, and maps were used to present the results. Arc-GIS (version 10.1) and ERDAS (2015) software were used to analyze data from field observations. This data was displayed using the method of supervised image classification.

Questionnaires

The SPSS (Statistical Program for the Scientific Solution) was used to evaluate the survey data that was recorded in Microsoft Excel. Tables, graphs, and visual statistics were used to present the results.

A voice recorder was used to record the interview proceedings. Data collected was analyzed using content analysis.

3.6 Ethical Considerations

To uphold ethical concerns, participants were informed of the purpose of the study, and they were given the option to join or decline at any moment. It was made clear to all participants that their information would be kept private and that they would not be identified by name.

3.6.1 Ethical Clearance

An ethical clearance certificate was applied for and granted by the University of Venda Research and Publications Office. The researcher only started conducting the upon clearance from the research office.

3.6.2 Informed Consent

To gain informed consent from the participants, the researcher informed the respondents about the aim and objectives of the study and asked them to sign a consent form before taking part in the study.

3.6.3 Voluntary participation

Participation in the study was voluntary and no one was forced to take part in the study. Respondents were free to withdraw from taking part in the study anytime they felt like doing so.

3.6.4 Confidentiality and anonymity

The data collected from the respondents would be used only for the purpose of the study. The collected data is kept in the laptop which is assessable through a password. The password is known by the researcher only and no one will be able to access the collected data.

3.6.5 No harm to participants

The researcher made sure that respondents are not harmed. To minimize the risk of harm, the participants' real names are not used. The researcher used code names to protect the anonymity and confidentiality of the participants.

3.6.6 Communicating the results

A journal article will be developed from this study and published in a peer reviewed research journal. This is the final step and one of the most important steps of the research process.

3.7 Chapter Summary

The research approaches and procedures employed in the study are described in this chapter, along with their rationale. The study methodology seeks to explain the research concept, data collection techniques and specific steps for participant sampling and data processing. Data collection used a variety of methods, techniques, and sources such as ArcGIS, document reviews, field surveys, remote sensing, and questionnaires were used for triangulation purposes. A triangulation of research methods and techniques was done to corroborate research findings. This includes utilizing.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents, analyzes, discusses, and interprets the results of the study. The discussions are centered on interpreting the consequences of recent and historical land use change dynamics on wetlands after mapping small-scale farming activities in wetlands. The chapter also discusses how the locals feel about the effect of farming on wetlands. Each of the themes from the major findings is compared with past research to assess whether compatibility.

The results are presented in tables, graphs and maps highlighting the changes in land use and cover. Each topic includes empirical evidence that tries to explain the unique findings related to the study issues. The analysis has been split into three sections according to three research objectives.

4.2. Mapping small-holder farming activities using Unmanned Arial Vehicle

4.2.1 Image categorization using a remote sensing/GIS approach.

The objective's aim was to select satellite images that could provide enough information for the investigation. These photos selected were of the 1st of November to 31st of November 2014, 2018, and 2022 respectively. During the years 2014, 2018 and 2022, respectively, the region covered by the principal land use/cover categories was investigated. UAV and Landsat 8 OLI were used to classify changes in land use and cover. Four categories of land use/cover have been established: water, cultivation, vegetation and bare (bare land) (natural). It was found that various land uses and covers changed between 2014, 2018 and 2022. Here are the outcomes of the land use/cover status photos.

4.2.2. Image classification of 2014

A satellite image from November 2014 with less than 25% cloud cover was utilized to classify the 2014 image. Table 3 below displays the land usage and cover for 2014. Vegetation (Natural) land use/cover, comprising of 122 hectares of total land, was determined to be the major land use/cover in this classification. The Phadzima wetland region in Figure 4 was dominated by the natural vegetation class because of the low human population of 4,106 in 2014 as compared to the population of 4,966 in 2022 and low agricultural operations (cultivation) (Nephawe, 2017) that occurred in the wetland and associated resources. Human influences on the marsh and its natural

resources are very minimal when the population is low, Phadzima-Tshitavha had a population of 4,106 in 2014 as compared to 4,966 in 2022 (Tintswalo, et al., 2022).

According to the findings, 43 hectares of uncultivated land were covered in 2018, as opposed to 96 hectares in 2014. Because water covered 22 hectares, it can be deduced using change detection analysis that the community had only slightly damaged that region (Figure 4). The IPAT model, which asserts that population expansion and overpopulation are significant causes of environmental harm, supports this (Nephawe, 2017). Due to the low population (4106) in 2014, there were fewer environmental consequences on the wetland area in this instance of Phadzima. 283 hectares of land were used for the investigation. Table 3 presents all these data, as shown in Figure 4 and Figure 5 displays the categorized map, while Figure 6. depicts the change in land use/cover for the year 2014. The overall classification accuracy assessment result was discovered to be 84% as shown in Table 3.

Table 3: Land use/cover classes 2014 (ha)

CLASSES	AREA COVERED (HA)	AREA IN PERCENTAGE
Water	22	7.77
Barren (Bare Land)	43	15.19
Cultivation	96	33.92
Vegetation (Natural)	122	43.12
TOTAL	283	100

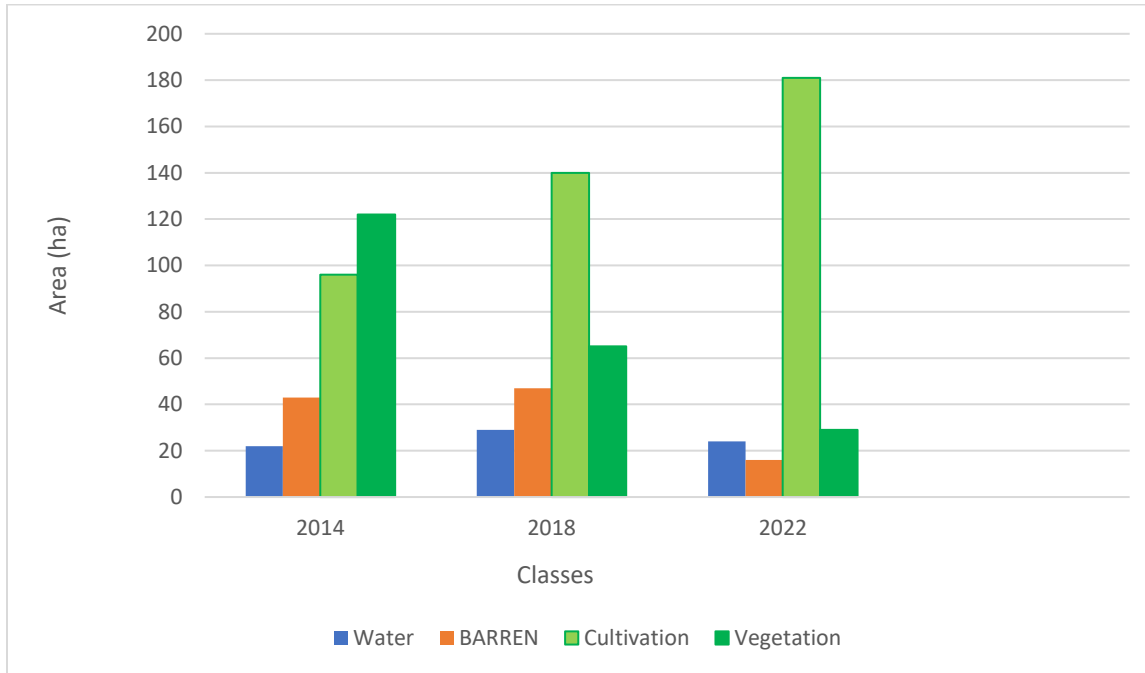


Figure 4: Land use/cover classes 2014, 2018 and 2022 (ha)

Figure 4 shows that even when cultivations increase in area size, the water resources remain the same while showing a slight increase; this could indicate water management strategies in the area.

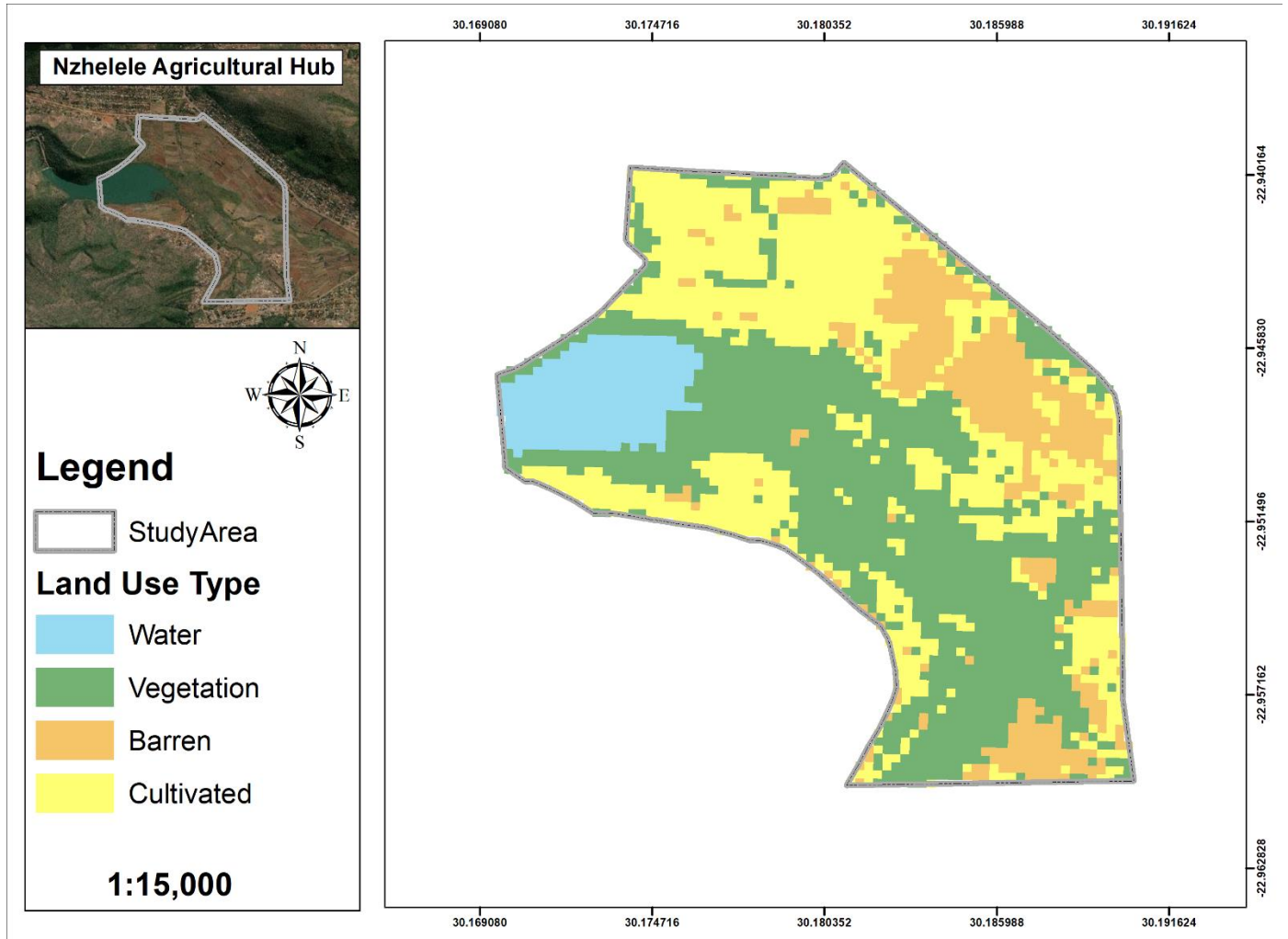


Figure 5: Land use/cover map 2014

Table 4: Land use /cover classes classification accuracy assessment report for 2014

CLASS VALUE	WATER	VEGETATION	BARREN	CULTIVATED	TOTAL	P_ACCURACY	KAPPA
WATER	2	0	0	0	2	1	0
VEGETATION	0	21	1	4	26	0.807692308	0
BARREN	0	0	7	1	8	0.875	0
CULTIVATED	0	2	0	12	14	0.857142857	0
TOTAL	2	23	8	17	50	0	0
P_ACCURACY	100%	91%	88%	71%	0%	84%	0%
KAPPA	0%	0%	0%	0%	0%	0%	75%

The overall kappa was found to be 75%, while the overall accuracy was 84%, which only means that many pixels were properly categorized.

4.2.3. Image classification of 2018

For the classification of 2018 image, a satellite image of 31 November 2018, was utilized to show constant changes. The 2018 land use and cover are displayed in Table 5. Data from 2018 and 2014 were compared in terms of land use cover. Compared to 2014, when there were 43 hectares of bare land, there are now 47 hectares of bare land, with 281 hectares of total land use/cover. Compared to 2014, when there were 96 hectares under cultivation, there are now 140 hectares under cultivation. This is because water levels in the wetland area have increased from 22 hectares in 2014 to 29 hectares in 2018.

In the wetland area, a change detection analysis for the 2018 image revealed a sharp rise in agricultural activities and a sharp reduction in natural vegetation. Because there was more water available in the wetland area that year, there was an increase in cultivation. This had an influence on the wetland ecology, causing soil erosion, a loss of biodiversity and agricultural activities. Land use/cover change for the year 2018 is depicted in Table 5 and Figure 4 and the categorized map is shown in Figure 6; the overall classification accuracy evaluation was 88% (Table 6).

Table 5: Land use/cover classes 2018(ha)

CLASSES	AREA COVERED HA	AREA IN PERCENTAGE
WATER	29	10.32
BARREN (BARE LAND)	47	16.73
CULTIVATION	140	49.82
VEGETATION (NATURAL)	65	23.13
TOTAL	281	100

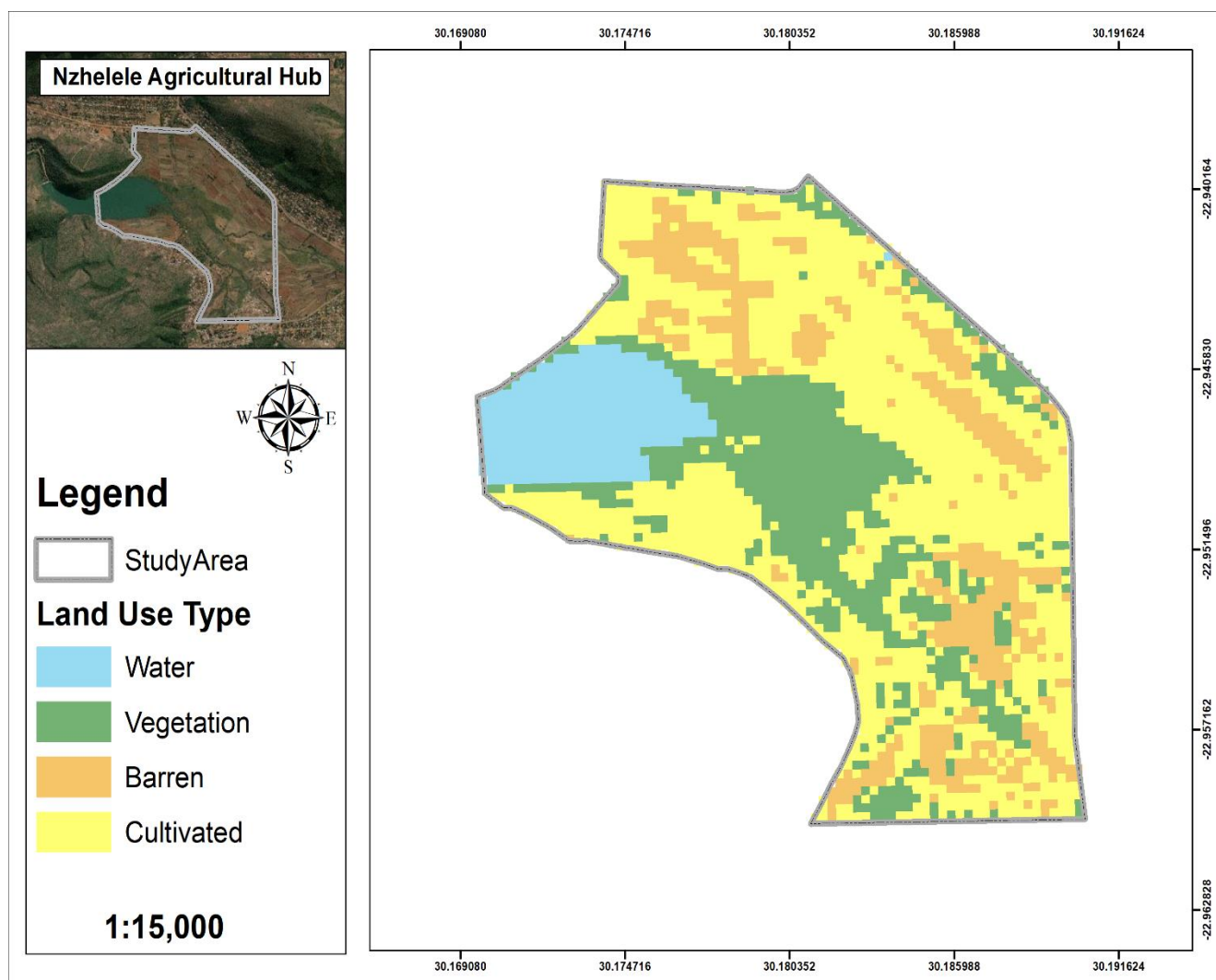


Figure 6: Land use/cover map 2018

Table 6: Land use/cover classes classification accuracy assessment report for 2018

CLASS VALUE	WATER	VEGETATION	BARREN	CULTIVATED	TOTAL	P_ACCURACY	KAPPA
WATER	9	0	0	0	9	100%	0
VEGETATION	0	11	0	0	11	100%	0
BARREN	0	0	5	2	7	71%	0
CULTIVATED	0	2	2	19	23	83%	0
TOTAL	9	13	7	21	50	0%	0
P_ACCURACY	100%	85%	71%	90%	0%	88%	0%
KAPPA	0%	0%	0%	0%	0%	0%	83%

The overall kappa was 83% and the overall accuracy was found to be 88%, which means that many pixels were properly categorized. If not, the classification of overall accuracy would be unacceptably low as accuracy is complement of the Omission Error, according to GPS, 2016 introduction to remote sensing.

4.2.4. Image classification of 2022

Using a drone (UAV) image from November 29, 2022, the 2022 image was classified. Table 7 shows the land cover and use in the year 2022. Also, noted was the fact the area under cultivation was expanding, gaining 181 hectares over the previous years. According to change detection analysis, by 2022, the land use/cover pattern of Phadzima Wetland has undergone a considerable change. It has been discovered that agricultural regions (cultivation) have had a substantial role in the alteration of wetland throughout the study period, except for the year 2014. As a result of the expansion of various land use activities, such as human settlement areas and agricultural sites, environmental effects rose along with population growth. The amount of water has dropped to 24 hectares from the previous year due to an increase in land use activities. Due to the rise in human settlements and farming operations, natural vegetation has decreased from 65 hectares in 2018 to 29 hectares in 2019.

The amount of bare ground has substantially decreased from prior years by 16 hectares. All this data is shown in Table 7 below, which represents land use/cover in 2022. Figure 4 depicts the change in land use and cover for the year 2022, and Figure 7 shows the classified map. The assessment of categorization accuracy is also shown in the table (Table 8) below.

Table 7: Land use/ cover classes 2022

CLASSES	AREA COVERED HA	AREA IN PERCENTAGE
WATER	24	9.6
BARREN (BARE LAND)	16	6.4
CULTIVATION	181	72.4
VEGETATION (NATURAL)	29	11.6
Total	250	100

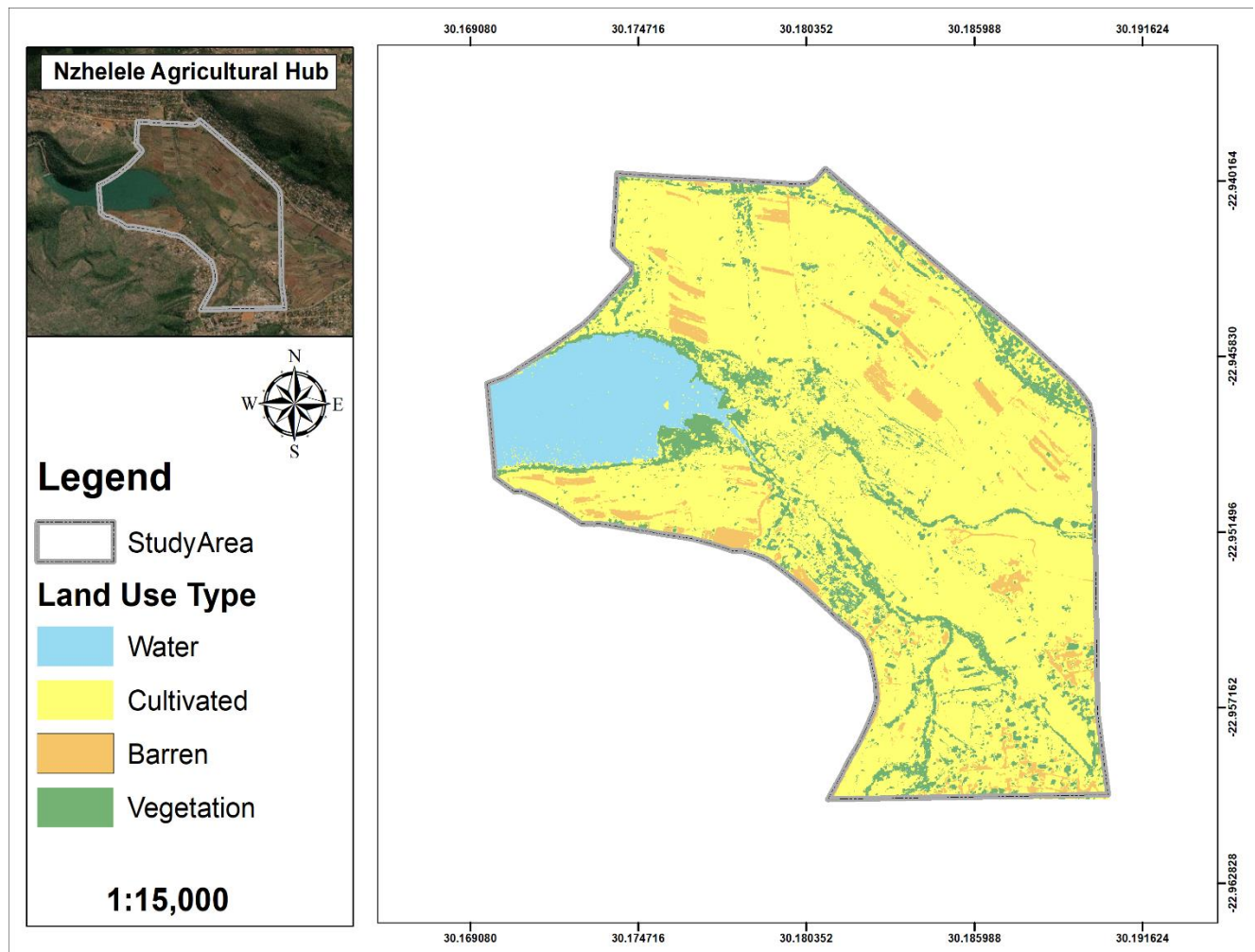


Figure 7: Land use/cover map 2022

Table 8: Land use/cover classes classification accuracy assessment report for 2022

CLASS VALUE	WATER	CULTIVATE D	BARREN	VEGETATION	TOTAL	P_ACCURACY	KAPPA
WATER	5	0	0	0	5	100%	0
CULTIVATE D	0	27	3	7	37	73%	0
BARREN	0	0	5	0	5	100%	0
VEGETATION	0	0	0	3	3	100%	0
Total	5	27	8	10	50	0%	0
P_ACCURACY	100%	100%	63%	30%	0%	80%	0%
KAPPA	0%	0%	0%	0%	0%	0%	64%

The overall accuracy was discovered to be 80%, while the overall kappa was 64%, demonstrating the number of identified pixels at this time. According to this research, the overall precision evaluation was, on average, above 80%, meaning that most pixels were correctly detected.

4.3. The effects of small-holder farming activities in wetland areas

According to Figures 5, 6 and 7, the land use and cover in the area changed at Phadzima village between 2014, 2018 and 2022. The evaluated land uses and covers were:

4.3.1 Change in water bodies

With a total shift of 12 hectares in the overall area over the course of the study, water covered an area of approximately 22 hectares in 2014, 29 hectares in 2018, and 24 hectares in 2022. The burning of marsh vegetation, excessive use of wetland resources for handicraft production and water consumption, as well as farming operations, were among the anthropogenic activities that caused the water loss in the Phadzima wetland. Refer to figure 4, the area of the water is not stable, it is decreasing and increasing. This was evidenced by the presence of extensive irrigation systems and the clearing of land for agricultural purposes. In Chennai's coastal region, Tiner (2016) discovered that human activities including the development of residential areas and infrastructure had changed the flooded area. This study supports a previous result by De Klerk et

al. (2016) that the drop in water supply in the Illubabora zone was caused in part by the drainage of wetlands.

4.3.2. Change in bare Land (barren)

This sort of terrain is frequently found around wetland areas that follow streams and are used for agricultural purposes. Findings indicate that bare land degraded over the course of the study (2014 to 2022), with a total change of 45 hectares in the study's entire area. A section of the wetland has been vulnerable to erosion due to diverse land use activities like farming and human activity. So, there is a strong possibility that unsustainable land use activities such as deforestation, overgrazing, monoculture agriculture, and urban sprawl, among others can have significant negative impacts on ecosystems and the environment. will contribute to erosion if they are conducted in areas where erosion is likely to occur. Due to diverse land uses which are used in the area, the bare land in Phadzima wetland's land cover changed as expected. Near the Phadzima wetland, the increased cultivation of seasonal crops including cabbage, tomatoes, maize, sweet potatoes and ground nuts has resulted in erosion issues like low water table and habitat change (loss of biodiversity).

Research by Brown et al. (2013), which found that soil erosion had a negative influence on Kenya's Nyando wetland because of floods and poor farming practices that led to the deposition of slit in the wetland, is supported by the findings of this study. Moreover, Stagg et al. (2020) noted that agricultural regions' soils are vulnerable to erosion, which may be particularly important in vulnerable areas like steep slopes or adjacent to streams. The rapid deforestation in the vicinity of the wetland area, which stripped the land of its vegetation cover and left it naked and exposed, was the primary cause of the increased soil erosion in Pakistan's bare soil, according to the findings of related studies by (Simberloff, 2013).

4.3.3 Change in cultivation and vegetation

Cultivation covered 96 hectares in 2014, 140 hectares in 2018 and it increased rapidly to 181 hectares in 2022, the area of cultivation has been showing an increasing rate over the years of 40 hectares plus. These findings are consistent with the analysis of the study by Banson, Nguyen & Bosch (2018) that indicated that most of owners are unable to cultivate the land due to lack of money to purchase seeds, shortage of water and pay for the truck services however according to the respondents, those owners whom are unable to cultivate the land, end up leasing the certain

hectares which they own to those who can afford it and other buy pumps to pump the water straight from the water bodies and use drips to irrigate their plants.

Certain areas of the wetland in Phadzima, experienced significant alterations, and these were regions that had been substantially drained and converted to agriculture or other land uses like grazing land. Parts of the Phadzima Wetland were entirely drained to make way for field crops such maize, sweet potatoes, ground nuts and butternut. The likelihood of wetland vegetation regeneration or flooding during the rainy season was decreased because those regions were regularly farmed each year. This result is in line with Simberloff's (2013) investigation, which showed that removal of natural vegetation, domestic animal grazing and non-native species that compete with natives can all harm marsh vegetation. Findings of this study are consistent with those of Rebelo et al. (2018), who found that population migration to the wetlands environment has resulted in biodiversity loss due to the wetlands ecosystem's appropriateness for farming and ease of access to water for cultivation and subsistence. Inadvertently or actively introducing invasive species can put pressure on native plants and eventually drive them out of their natural environment. Wetland vegetation is a crucial part of the ecosystem because it stabilizes the soil, offers animals a home and food and contributes to the maintenance of a healthy wetland.

4.4 The impacts of farming on wetland

According to the findings of the study, the wetland is being impacted by farming on wetland area. The results show that 17.7% of people know that farming on wetlands has an impact whereas 66.1% said farming does not impact the wetland. Others (12.2%) did not know or were not sure that farming on wetlands has an impact on wetlands. In addition, most of the respondents indicated that people who cultivate in and around the wetland used organic and non-organic fertilizers and pesticides which may have leached into the wetland. The use of pesticides and fertilizers in certain areas of the wetland has resulted in a reduction in the diversity of wetland plants and animals (Table 9). As a result of too many pesticides leaching into the wetland, its ability to clean water was diminished. This was demonstrated by the presence of common grasses like water grass and bird species like duck, were no longer found in the study area.

Table 9: Impact of farming in Phadzima wetland

		FREQUENCY	PERCENT	VALID PERCENT	CUMULATIVE PERCENT
VALID	Yes	11	17.7	17.7	17.7
	No	41	66.1	66.1	84.8
	Don't know/ not sure	8	12.2	12.2	100.0
	Total	61	98.4	100.0	
MISSING	System	1	1.61		
TOTAL		62	100.0		

4.4.1. Water shortage

All respondents who settled in the area during the 1990's indicated that the human population was not high and there was enough water for all residents unlike now where they are facing water shortages and can no longer cultivate in the area. Therefore, they are leasing to those who can pump water and use drip for irrigation. According to the findings, 93.5% of respondents said there is a water deficit in the area, while only 6.5% said there is no water shortage in the area. As a result of water shortage, they end up cultivating vegetation which do not demand a lot of water such as sweet potatoes and tomatoes see Figure 9 and 10 The respondents indicated that they are days allocated for irrigation for each block. However, sometimes it can take several weeks without water and other farmers hijack irrigation (see Figure 13) days for others.

The different respondents and farmers indicated that they use water from the wetland for cultivation of maize, potatoes, ground nuts and other plants. Moreover, water was utilized for domestic uses, especially when the municipality could not provide water and for the irrigation of crops that were grown in and near marsh areas. Water is also used for other purposes such as building construction, brickyard, and car wash, as a result this is contributing to the wetland drying up and shortage of water (Table 10).

Table 10: Water shortage In Phadzima

		FREQUENCY	PERCENT	VALID PERCENT	CUMULATIVE PERCENT
VALID	Yes	58	93.5	93.5	93.5
	No	4	6.5	6.5	100.0
	Total	62	100.0	100.0	

4.5. Agricultural activities which are being done by small-holder farmers in Phadzima village:



Figure 8: Crop farming Nov/Dec 2022



Figure 9: Sweet potatoes Nov/Dec 2022



Figure 10: Ground nuts



Figure 11: Cabbage



Figure 12 :Farmer irrigating



Figure 13: Irrigation canal at the study area

4.5 Perception of locals on the effects of farming on wetlands areas.

This type of survey needed to be carried out to gather additional information about small-holder farmers' perceptions of how farming affects wetlands areas. Wetland is used for a variety of reasons, including washing clothing, providing grazing ground for livestock, producing handicrafts, extracting medicines, providing water for drinking and irrigation. Wetland degradation is the result of all these activities. The community most frequently uses the resources found in wetlands to produce food, followed by irrigation water. This is consistent with research from De Klerk et al. (2016), who discovered that the majority of South Africa's rural community relies on the ecosystem for food and medicine.

According to Kingsford et al. (2016), wetlands have been exploited for agriculture for a very long time. These include, among other crucial ecosystem services, the provision of food and clean water, soil preservation and nutrient cycling. Yet, the research by Neswiswi (2019) has shown that farming within or near wetlands had detrimental effects on farming. Farmers expressed their

concerns about the degradation of wetlands and recognize the need for sustainable land management practices to mitigate negative impacts on wetland ecosystems.

4.5.1 Farming activities

Table 11 shows the farming activities in Phadzima village. All the respondents practicing farming in the area indicated the activities which they were practicing. Of the 62 individuals who claimed to be engaged in farming in the region, 17.7% indicated that they are doing subsistence farming to provide food for themselves and their family, 37.1 % indicated that they are practicing commercial farming as a way of earning living. However, 45.2% were doing both commercial and subsistence farming. It was observed during data collection method that those who are doing both commercial and subsistence farming are the one who are mainly cultivating in the area.

Table 11: *Farming activities in Phadzima wetland*

		Frequency	Percent	Valid Percent	Cumulative Percent
<i>Valid</i>	Subsistence	11	17.7	17.7	17.7
	Commercial	23	37.1	37.1	54.8
	Subsistence and Commercial	28	45.2	45.2	100.0
	Total	62	100.0	100.0	

4.5.2 Crop cultivation

An agricultural plot was present in the study area around the wetland at the time of the research. In Tshitavha, where the study was conducted, this means that around the wetland, most of the natural vegetation was removed for the farmers to cultivate crops.

4.5.3. Maize

At the time of data collection, most farmers had cultivated maize (see Table 12). About 75.8% of respondents indicated that they use water from the wetland to irrigate the maize. These results align with the mapping activities of small-holder farmers analyses which indicated that during

2022, cultivation was very high compared to other activities, and it was also verified by the map (Figure 7, Land use/cover map 2022) and confirmed by the extension officer (Mulimisi).

Table 12: Maize production in Phadzima wetland

		Frequency	Percent	Valid Percent	Cumulative Percent
<i>Valid</i>	Yes	47	75.8	75.8	75.8
	Maize	15	24.2	24.2	100.0
	Total	62	100.0	100.0	

4.6 Past and present changes in land use dynamics in wetland areas

This section presents results of the social survey, remote sensing, and GIS techniques, which complement one another.

The survey results showed that wetlands are being degraded because of unsustainable use of the wetlands ecosystem, even though marsh in the research region is the source of numerous environmentally friendly materials that are directly or indirectly employed for diverse socioeconomic objectives. Changes in the composition and diversity of wetland plant species can indicate degradation. This can be assessed through vegetation surveys, where the presence of invasive species, decline in native species, or loss of sensitive wetland plants is noted. Additionally, the results show that the wetland's natural functioning has been significantly harmed by its conversion to agricultural and residential land uses, leaving it fragmented.

CHAPTER 5: SYNTHESIS AND SUMMARY OF THE STUDY

5.1 Synthesis

The dissertation is composed of 5 chapters:

Chapter 1: This chapter provided the introduction of the study, the background of the study, problem statement was also elaborated in this chapter, the aim and objectives of the study, hypotheses and explains why the study is important were also introduced. This chapter also provided the operational definitions of the terms commonly used throughout the dissertation and the outline of dissertation.

Chapter 2: The extant literature about land use/cover issues is reviewed in this chapter. This chapter reviewed the farming practices in wetland, the rate of wetland degradation and loss attributed to farming activities, the impact of farming practices on wetland ecological conditions and the integration of remote sensing on wetland ecological conditions assessments that included the application of remote sensing, challenges, opportunities, and the advantages of Landsat 8 and the UAV.

Chapter 3: Explains the research's topic area, methodology, sampling size, data gathering tools, and data processing techniques. This chapter provided the description of the study area, research design, research methodology that covers data collection and analysis methods. This chapter also provided the ethical considerations.

Chapter 4: Discusses and summarize the key study findings, their interpretation, and implications for the research topics and body of knowledge. The chapter provided the analysis on the following aspects: Mapping small-holder farming activities using Unmanned Arial Vehicle (UAV) in wetland areas, the effects of small-holder farming activities in wetland areas, the impacts of farming on wetlands, the perceptions of locals on the impacts of farming on wetland areas, as well as past and present changes in land use dynamics in wetland areas.

Chapter 5: Describe how the results relate to the study's goal and provide the summary of the study.

Chapter 6: This chapter provided the conclusions and recommendations of the study.

The main purpose of the study was to evaluate the effects of small-holder farming operations on wetland area in Nzhelele Agricultural Hub in the Vhembe District, Limpopo Province. To achieve this aim three objectives were formulated which correspond to the steps taken in evaluating the effects of farming on wetland area. As such the first objective sought to map small-holder farming activities in the wetland area using UAV images. The second objective examined the impact of the present and past land use change dynamics on the wetland area. The third objective determined the perceptions of locals on the effects of farming on wetland areas. This chapter summarizes the results of the study, draws conclusions, and make recommendations based on the findings of the study.

5.2 Summary of study findings

The study titled "Assessing the Impacts of Small-Holder Farming Activities on Wetland Area in Nzhelele Agricultural Hub in the Vhembe District, Limpopo Province, South Africa" was to assess the impacts of small-holder farming activities on wetlands in the Nzhelele Agricultural Hub in the Vhembe District, Limpopo Province.

The study employed a combination of remote sensing techniques, social surveys, and field observations to collect data and analyze the impacts of small-holder farming activities on wetland areas. Remote sensing methods were used to acquire satellite imagery and map wetland areas within the study area. Various remote sensing indices and techniques were utilized to assess wetland extent, changes in vegetation cover, and overall wetland health over time.

Social surveys were conducted to gather information on small-holder farming practices, land use patterns, irrigation methods, and other relevant socio-economic factors. These surveys aimed to understand the farming activities that have direct or indirect impacts on wetland areas. Field observations were carried out to validate and complement the remote sensing and survey data. Researchers visited selected small-holder farms and wetland areas to assess the physical condition of the wetlands, identify specific farming practices affecting wetlands, and document any visible signs of wetland degradation.

The collected data from remote sensing, social surveys, and field observations were integrated and analyzed to assess the impacts of small-holder farming activities on wetland areas. Statistical analyses and spatial modeling techniques were employed to examine the relationships between farming practices and wetland degradation. The study concluded by providing insights into the extent and nature of the impacts of small-holder farming activities on wetland areas in the

Nzhelele Agricultural Hub. It identified specific farming practices that contribute to wetland degradation, such as improper land clearing, unregulated irrigation, or the use of agrochemicals.

The findings of the study can be used to inform policy and management strategies aimed at promoting sustainable small-holder farming practices and conserving wetland ecosystems. Recommendations may include the implementation of best management practices, awareness campaigns, or regulatory measures to mitigate the negative impacts on wetlands while supporting the livelihoods of small-holder farmers. Overall, the study contributes to the understanding of the complex interactions between small-holder farming activities and wetland areas, emphasizing the need for sustainable agricultural practices to ensure the long-term conservation and protection of wetland ecosystems in the Nzhelele Agricultural Hub.

Chapter 6: conclusions and recommendations

6.1 Conclusions

This study was aimed at assessing the impacts of small-holder farming activities on wetland area in Nzhelele Agricultural Hub using remote sensing datasets and questionnaire. In this study, the Landsat 8 and UAV data were used for assessing the impacts of small-holder farming activities and the questionnaire was used to determine how locals perceive the effects of farming on wetlands areas at the Nzhelele agricultural hub. Three satellite images for the year 2014, 2018 and 2022 were used for mapping the land use and cover. The results of this study indicated that cultivation /farming is the major activity within the wetland area over the years, from 2014 to 2022 and it is showing an increase at an alarming rate from 96 hectares to 181 hectares. The results show that even when cultivation in the area is increasing, the water level remains the same while showing a slight increase. It also shows that small-holder farmers are not well educated about wetland and do not have knowledge about the effects that farming activities have in wetland area. The study recommends the incorporation of additional data sets, such as Sentinel-2 and other sources of high-resolution optical data, future research.

The finding of this study indicated that Small-holder farming activities can lead to wetland degradation through practices such as land clearing, drainage, and conversion of wetland areas into agricultural fields. These activities can result in the loss of wetland habitat, reduction in wetland area and biodiversity, and alteration of hydrological regimes. Moreover, the study findings indicated that the impacts of small-holder farming on wetland areas can have socio-economic implications for local communities. Wetlands often provide resources for livelihoods, such as fishing, water supply, and non-timber forest products. When wetland health is compromised, it can negatively affect the socio-economic well-being of communities dependent on these resources.

The findings of the study can be used to inform policy and management strategies aimed at promoting sustainable small-holder farming practices and conserving wetland ecosystems. Recommendations may include the implementation of best management practices, awareness campaigns, or regulatory measures to mitigate the negative impacts on wetlands while supporting the livelihoods of small-holder farmers.

It is important to note that the conclusions drawn are specific to the Nzhelele Agricultural Hub in the Vhembe District of the Limpopo Province, and further research and monitoring may be

required to assess the generalizability of the findings to other similar agricultural areas in South Africa or elsewhere. The research study findings will contribute to the understanding of the complex interactions between small-holder farming activities and wetland areas, emphasizing the need for sustainable agricultural practices to ensure the long-term conservation and protection of wetland ecosystems.

6.2 Recommendations

The study only offered a preliminary understanding of the issue of assessing land use/cover change at the Phadzima wetland area using remote sensing, GIS, and social survey. It is important to note that mitigating the negative impacts of small-holder farming on wetland areas is possible through the adoption of sustainable land management practices. Implementing measures like agroecological approaches, land-use planning, and conservation strategies can help minimize the adverse effects on wetland ecosystems while supporting the livelihoods of small-holder farmers.

The following recommendations were made specifically for future work:

1. Wetland management committee members must recognize the full range of stakeholders who use these areas and include them in all wetlands decision-making processes to manage wetland resources responsibly. These campaigns or programs should be targeted at the local community as well as local small-holder farmers. Doing so would guarantee that wetland use is both socially, environmentally, and economically responsive to community demands.
2. To improve wetland management in Phadzima, information from both indigenous and foreign sources must be acquired through diverse routes. Basic knowledge on managing wetlands should be made available to small-holder farmers through the transmission of ancestral knowledge.
3. The government must map the wetland environment to prevent further damage due to cultivation and population growth through its work on the wetland program. By doing so, damaged wetlands might be restored and natural habitats for growing animals and plants could be created.
4. Further analysis of the effects of farming in wetland areas is recommended to care for wetland area.

5. Regular assessments of additional research on various anthropogenic and natural causes and drivers of wetlands ecosystem land cover change are required to care for the environment.

By implementing these recommendations, stakeholders can work towards sustainable small-holder farming practices that minimize the negative impacts on wetland areas while supporting the livelihoods of local communities. The preservation of wetland ecosystems is crucial for maintaining biodiversity, regulating water resources, and promoting environmental sustainability in the Nzhelele Agricultural Hub and similar agricultural regions.

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APPENDICES:

Appendix I: Research 40 Questionnaires were used in the study.

1. Gender of the Participant?
 - A. Female
 - B. Male
2. Age group of participants?
 - A. 65+
 - B. 55-65
 - C. 45-55
 - D. 35-45
 - E. 20-35
3. How many ha do you own?
 - A. 1.3 ha
 - B. 2ha
 - C. 3ha
 - D. 4ha
4. Position
 - A. Owner
 - B. Lease
 - C. Other
5. Land Tenure Type?
 - A. Private
 - B. Communal
 - C. Leased land
 - D. State-owned land
6. Ownership-type?
 - A. Phadzima Residents
 - B. Neighboring Residents
 - C. Other
7. Main Livelihood from owner?
 - A. yes
 - B. No
8. Types of farming activities done.

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9. If crops, which type.

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.....

10. Which type of manure do use for your plants?

- A. Organic
- B. Inorganic
- C. Both

11. When do you normally cultivate?

- A. Annually
- B. Seasonally
- C. All year round

12. Where do u get irrigation water from?

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13. Do you think cultivating this land has a negative impact on the wetland?

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14. What are the challenges that you are faced with as a farmer here?

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15. Do you think/ see tailing of this land contribute towards its drying up?

A. Yes

B. No

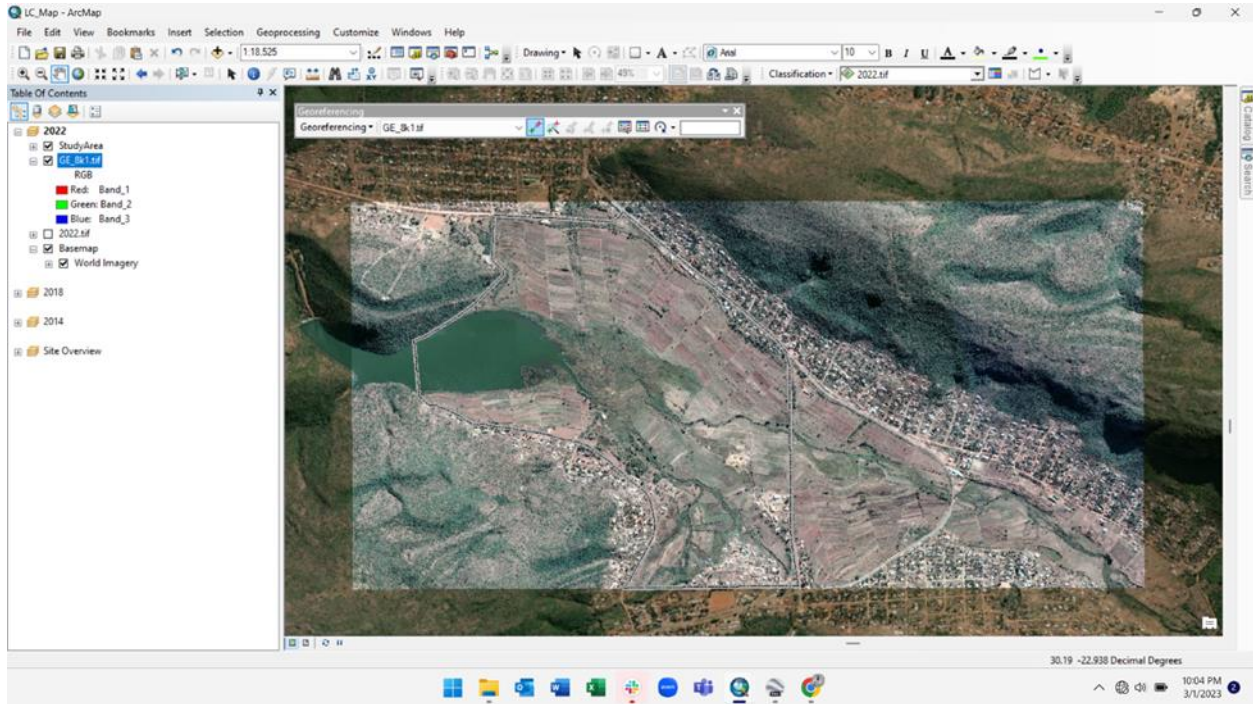
16. Which strategies can be used to prevent wetlands from drying up?

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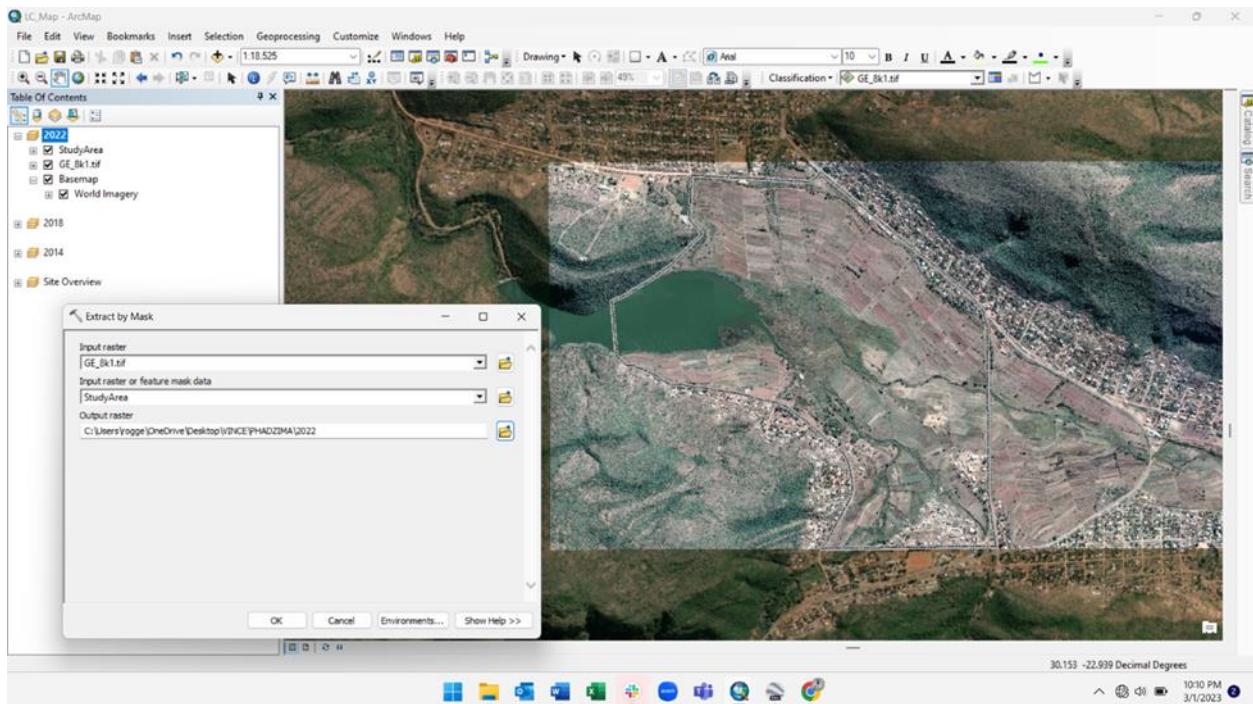
Additional Notes

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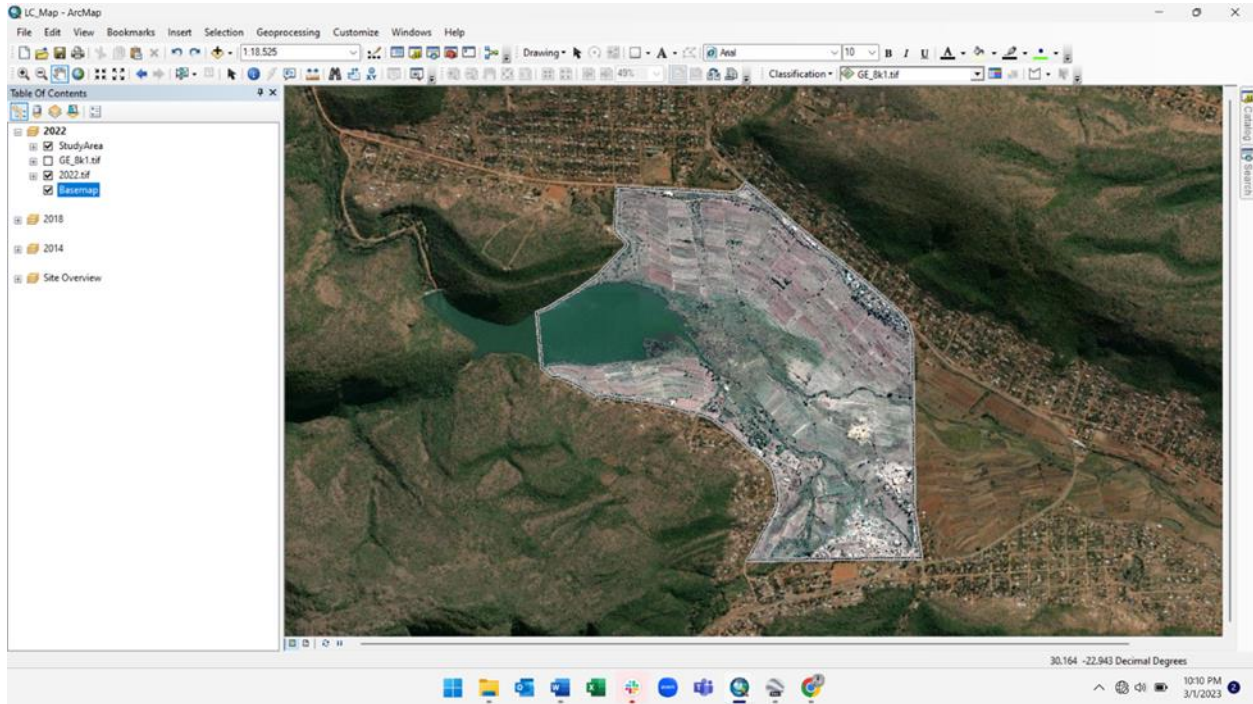
Appendix II: Images Processing



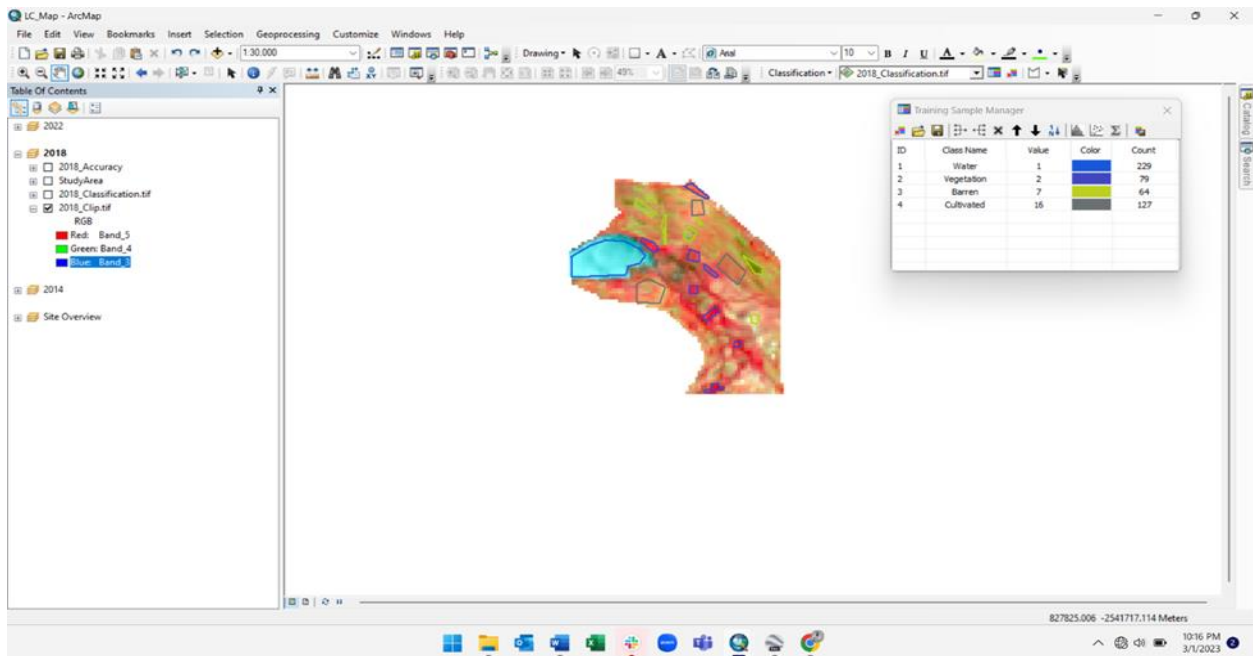
Appendix III: Geo-referencing image



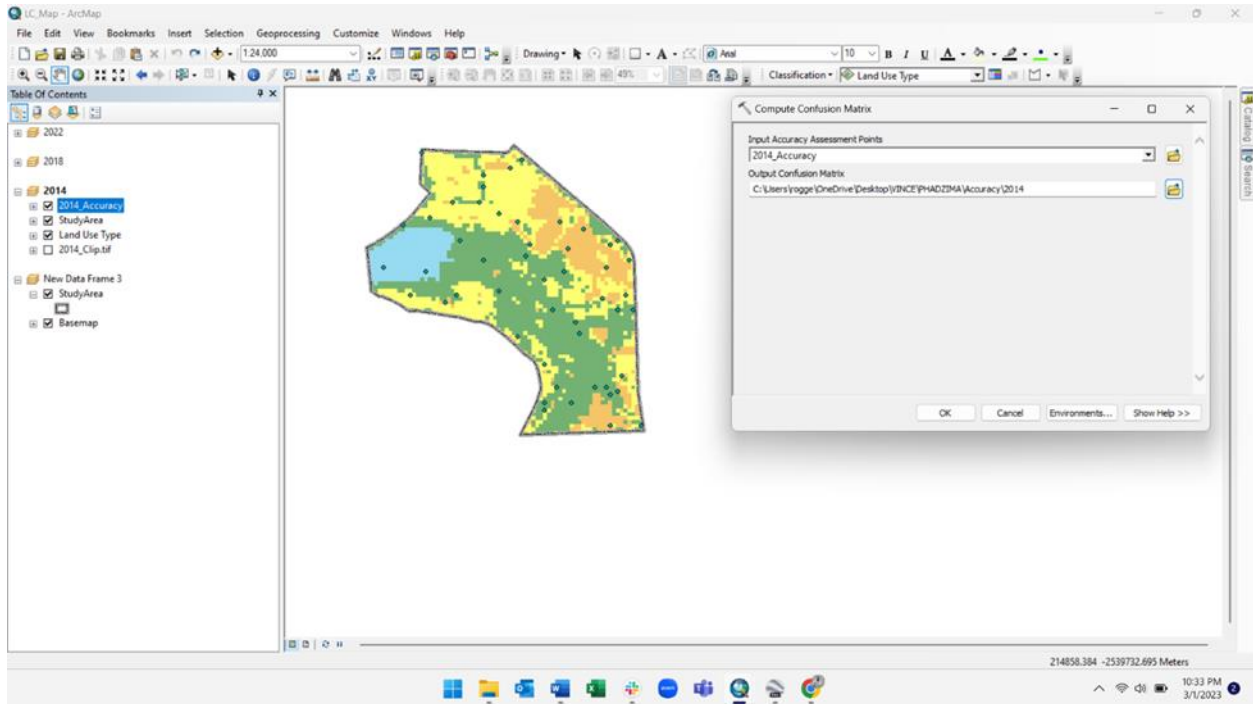
Appendix IV: Extracting study area from geo-referenced image



Appendix V: Study area extracted



Appendix VI: Creating training samples for image classification.



Appendix VII: Running accuracy assessment

