THE EFFECT OF WETLAND USE AND COVER CHANGES ON PLANT DIVERSITY IN MASESE-BUDHUMBULI WETLAND, JINJA CITY, EASTERN UGANDA

BY

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DECLARATION

I Namatovu Faridah declare that the contents of this research thesis are original, except where referenced and it has never been presented to any university or institution for any award.

Date …………………………………………...

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APPROVAL

I have supervised and checked this research proposal in my observation, outlook and scrutiny, this proposal meets the required standards of Kyambogo University.

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DEDICATION

This work is dedicated to first and foremost to the Almighty Allah for the strength, wisdom, and perseverance that guided me throughout the course of my studies and the completion of this research, my lovely family especially my loving husband, our wonderful children who have been my source of peace and happiness during the hard times of research, to my dedicated workmates, classmates, mentors, and supervisors, whose guidance, collaboration and encouragement have shaped this research.

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ANOVA	Analysis of variance
CVA	Change Vector Analysis
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
FGDs	Focus Group Discussions
GIS	Geographical Information System
GPS	Global Positioning System
ISODATA	Iterative Self Organizing Data Analysis
LC	Local Council
MCA	Multi Criteria Decision Analysis
MNDWI	Modified Normalized Difference Water Index
MODIS	Moderate Resolution Imaging Spectroradiometer
MWD	Wetlands Management Department
MWE	Ministry of Water and Environment
NBR	Normalized Burn Ratio
NDVI	Normalized Difference Vegetation Index
NWIS	National Wetland Information System
OBIA	Object Based Image Analysis
RF	Random Forest
RMLands	Rocky Mountain Landscape Simulator
RS	Remote Sensing
SRV	Simulated Range of Variation
TD	Transformed Divergence

ABSTRACT

Wetlands are vital for sustaining local livelihoods and providing essential ecosystem services. However, in Uganda, unsustainable wetland use has led to significant degradation. Some wetland plant species are resilient to environmental stresses including changes in land use and land cover. There is limited knowledge about the extent of wetland use and cover changes in the Masese-Budhumbuli wetland and how plant species adapt to these changes. The study aimed to assess the effect of wetland use and cover changes on plant diversity in Masese-Budhumbuli wetland, Jinja City, Eastern Uganda. The study examined the extent and drivers of wetland use and cover changes; determined the effect of wetland use and cover changes on plant diversity; and assessed the ecological resilience of plants to wetland use and cover changes. Satellite images for the years (1993, 2003, 2013 and 2023) utilized. Unsupervised classification was employed to analyze the magnitude of wetland use and cover changes. Plant species data was collected and identified from the Makerere University Herbarium. Multi-criteria decision analysis was applied to evaluate the ecological resilience of plant species in response to wetland use and cover changes. To understand the drivers of wetland, use and cover changes and the plant species resilient to disturbances, household interviews, key informant interviews, and focus group discussions were conducted. The findings revealed that substantial changes in wetland use and cover, with farmlands (33.2%) built-up areas (7.4%) and tree plantations (2%) increasing, while grasslands (17.7%) and papyrus (26.1%) declined significantly. Key factors contributing to wetland use and cover changes included the development of industries and housing, rapid urban growth, rising poverty levels, population pressure, and increased crop farming. Changes in wetland use and cover had no statistically significant effect on plant diversity ($P > 0.05$). A total of 103 plant species were recorded mostly herbs showing high ecological resilience. The correlation between wetland use and cover changes and ecological resilience established to be was weak but statistically significant ($P<0.05$). *Cyperus papyrus*, *Rubia cordifolia*, and *Digitaria scalarum* were perceived by communities to be mostly resilient to wetland use and cover changes. The study concludes that despite the wetland use and cover changes, plant diversity remained largely unaffected, suggesting a degree of ecological stability in the wetland. The study recommends periodic monitoring of plant diversity, creation of wetland buffer zones, and restoration of degraded wetland sections.

CHAPTER ONE: INTRODUCTION

1.1 Background

Wetlands are among the most productive and ecologically valuable ecosystems on Earth, providing numerous ecosystem functions and services essential to human well-being and environmental stability. Characterized by water-saturated soils and vegetation adapted to hydric conditions, wetlands include swamps, marshes, and peatlands that perform vital ecological roles such as regulating water flow, improving water quality, sequestering carbon, and serving as habitats for diverse flora and fauna (Mitsch *et al*., 2015; Xu *et al*., 2020). Globally, wetlands occupy approximately 12.1 million square kilometers, supporting over 40% of all species (Fraixedas *et al*., 2019). Despite their ecological importance, these ecosystems are rapidly diminishing due to land conversion, pollution, and climate change (Dar *et al*., 2020).

In Uganda, wetlands cover about 31,411 square kilometers, representing roughly 13% of the national surface area (MWE, 2019). These ecosystems are integral to rural and urban livelihoods, particularly for communities that depend on them for agriculture, fishing, papyrus harvesting, and water supply (Namaalwa *et al*., 2013). Over 80% of wetland-adjacent populations in Uganda directly rely on wetland resources for income, food security, and cultural practices. However, wetlands have faced intense degradation in recent decades. Between 1994 and 2015, Uganda lost approximately 6,146 km^2 of its wetland area equivalent to 2.5% of the national land surface mainly due to agricultural expansion, urbanization, and industrial development (MWE, 2019). This loss has disrupted hydrological systems, reduced biodiversity, and undermined the provision of critical ecosystem services.

Jinja City, located in Eastern Uganda along the northern shores of Lake Victoria, has historically been one of the country's major industrial and commercial hubs. In the early to mid-20th century, Jinja's land use was dominated by natural wetlands, forested areas, and small-scale subsistence farms. The establishment of industries, beginning with the Owen Falls Dam in the 1950s, marked a turning point in the city's land use dynamics. Industrialization attracted a growing population, stimulating rapid urban expansion and infrastructure development (Isunju & Kemp, 2016). Over time, agricultural and natural landscapes were converted into residential, commercial, and industrial zones.

This urban expansion exerted significant pressure on surrounding wetlands, including the Masese-Budhumbuli wetland, one of the most extensive and ecologically important wetland systems in Jinja. The Masese-Budhumbuli wetland forms part of the Lake Victoria basin and functions as a natural buffer zone that filters industrial effluents, controls floods, and supports biodiversity. However, with continued population growth and weak enforcement of land-use regulations, large portions of this wetland have been encroached upon for agriculture, settlement, brick-making, and waste dumping.

Masese-Budhumbuli wetland provides immense socio-economic value to the communities around Jinja City. It supports local livelihoods through crop farming especially maize, rice, and vegetables fishing, papyrus harvesting, and small-scale livestock grazing. Its fertile alluvial soils are highly valued for agriculture, while papyrus and other wetland plants are harvested for handicrafts, thatching, and construction materials. The wetland also serves as an important water source for domestic and small industrial use, while its vegetation plays a vital role in filtering pollutants from urban runoff before they reach Lake Victoria. For many low-income residents in Masese and Budhumbuli parishes, the wetland provides an accessible safety net that sustains livelihoods in the absence of formal employment. Thus, the degradation of this ecosystem has direct implications for both ecological stability and socio-economic welfare.

In recent years, Masese-Budhumbuli Wetland has undergone visible degradation driven by uncontrolled human activities. Land-use/cover change analyses show marked conversion of wetland to agriculture and built-up areas in Masese-Budhumbuli (Namugabo, 2022). In the broader Lake Victoria basin, satellite imagery and field surveys indicate invasive plants like Eichhornia crassipes have expanded, altering vegetation cover and degrading wetland integrity (Kiyemba *et al*., 2023). Local reporting also highlights waste deposition, settlement intrusion and altered drainage in the area (Hamid, 2023). The reduction in vegetation cover has also weakened the wetland's capacity to filter sediments and pollutants, making Lake Victoria increasingly vulnerable to eutrophication (Van Dam *et al*., 2007). These changes not only compromise ecological balance but also reduce the wetland's capacity to sustain livelihoods, especially for communities that depend on its natural resources.

Understanding the interaction between land use and plant diversity is essential for assessing wetland health and resilience. Land use and wetland cover changes influence soil moisture, nutrient availability, and hydrological regimes, thereby determining the composition and distribution of plant species (Pillar *et al*., 2013). The conversion of wetlands to agricultural fields or built-up areas alters habitat structure and favors the dominance of invasive and stress-tolerant species at the expense of native hydrophytes (Were *et al*., 2019). This loss of native species reduces ecosystem resilience, as diverse plant communities provide functional redundancy that enables ecosystems to maintain ecological processes under stress (Elmqvist *et al*., 2003).

In Uganda, most wetland research has focused on mapping wetland cover transformations using GIS and remote sensing techniques, with limited integration of ecological and biodiversity data (Isunju & Kemp, 2016; Wasswa *et al*., 2019). Consequently, little is known about how these spatial changes translate into shifts in plant species diversity and ecosystem functionality. For Masese-Budhumbuli wetland, such information is crucial to understand how continued anthropogenic pressures affect ecological resilience and to guide restoration and management strategies.

To effectively manage and restore wetlands like Masese-Budhumbuli, there is a need for integrated studies that combine spatial analysis with ecological assessments and local community perspectives. Geographic Information Systems (GIS) and Remote Sensing (RS) provide valuable tools for detecting and quantifying wetland cover changes, while ecological field assessments help determine the impacts of those changes on vegetation diversity and wetland functioning. Integrating this information with local knowledge ensures that conservation strategies are context-specific, socially acceptable, and ecologically sound.

Assessing how land use and cover change influence plant diversity in Masese-Budhumbuli wetland will generate crucial insights into the extent of degradation and its implications for ecosystem resilience in Jinja City. Such information will support the design of sustainable management interventions that balance urban development with ecological conservation ensuring that wetlands continue to deliver essential services for both people and the environment.

1.2 Statement of research problem

Masese-Budhumbuli wetland, along the northern shores of Lake Victoria in Jinja City, is a vital socio-ecological system that supports local livelihoods and provides essential ecosystem services. However, the wetland is facing rapid degradation due to expanding anthropogenic activities like the predominant cultivation of rice, maize, yams, and cabbage has altered the wetland's vegetation structure, also industrial effluent discharge from facilities including Nile Transformers, Nile Derivatives, Nile Agro-Industry, Grain Bulk Handlers Terminal, and Bidco Uganda Limited, pose a serious risk to the health and balance of both the living (biotic) and non-living (abiotic) elements of the wetland (Ruffins, 2015) which have disrupted the natural ecological processes and increasing the loss of biodiversity (Kabiri *et al*., 2020). These changes have implications not only for faunal species but also for the composition, structure, and functional resilience of plant communities within the wetland.

Although wetlands are widely recognized for their ecological and economic importance, there is limited empirical data on how land use and cover changes are influencing plant species diversity and ecological resilience within the Masese-Budhumbuli wetland. There's limited data about the rate of native species decline, the spread of invasive plants, or the capacity of the ecosystem to recover from human-induced disturbances. Addressing this problem is critical because understanding the link between land use dynamics and plant diversity is essential for guiding effective conservation, restoration, and sustainable management. This study therefore aims to fill this gap by assessing how land use and cover change affect plant species diversity and ecological resilience in the Masese-Budhumbuli wetland, providing evidence to inform policies that balance urban development with ecological sustainability.

1.3 Objectives

1.3.1 General objective

The investigate the effect of wetland use and cover changes on plant diversity in order to understand their implications for ecological resilience and sustainable management of Masese-Budhumbuli wetland, Jinja city, Eastern Uganda

1.3.2 Specific objectives

I. To investigate the extent and drivers of wetland use and cover changes in Masese-Budhumbuli wetland, Jinja City.

II. To determine the effect of wetland use and cover changes on plant species abundance and richness for 2023 in Masese-Budhumbuli wetland, Jinja City.

III. To determine the ecological resilience of plant species to wetland use and cover changes in Masese-Budhumbuli wetland, Jinja City.

1.3.3 Hypothesis

HO1: There are no significant changes in wetland use and cover of Masese-Budhumbuli wetland between 1993, 2003, 2013 and 2023.

HO2: The changes in wetland use and cover types do not significantly influence plant diversity in Masese-Budhumbuli wetland.

HO3: There is no significant relationship between plant ecological resilience and wetland use and cover changes in the Masese-Budhumbuli wetland, Jinja City.

1.4 Significance of the study

The study generated information on plant diversity, the extent of wetland use and cover changes, the perceived drivers of these changes, and the ecological resilience of plants in the Masese-Budhumbuli wetland. The study will contribute data to the wetland inventory in the National Wetland Information System (NWIS) at the Ministry of Water and Environment (MWE). The information generated will guide the Jinja City Authority, the Wetlands Management Department (WMD), and partners in developing a community wetland management plan to guide the sustainable utilization of the Masese-Budhumbuli wetland. Similarly, the generated information will help the local government, the ministry, and partners seek financial resources to restore the degraded sections of the wetland. The study will also contribute to the realization of the 4th Strategic Plan of the Ramsar Convention (2016-2024) through documenting the extent and drivers of wetland use and cover changes in Masese-Budhumbuli wetland.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This section provides a synthesis of existing knowledge on wetlands, focusing on their ecological and socio-economic importance, the ways local communities utilize them, and the factors influencing their structure and function. It examines the values and uses of wetlands by communities, methods for quantifying wetland use and cover changes, the drivers of wetland transformation, and the diversity and resilience of wetland plant species. By integrating global, regional, and site-specific studies, this review highlights knowledge gaps, particularly in urban wetlands such as Masese-Budhumbuli in Jinja City, and establishes the conceptual foundation for understanding how human activities and ecological factors interact to shape wetland sustainability and resilience.

2.2 Values and local community uses of wetlands

Wetlands are globally recognized as vital ecosystems that provide multiple ecological and socio-economic services essential for human well-being (Maltby & Acreman, 2011). They contribute to water purification, flood regulation, nutrient cycling, and biodiversity support while sustaining livelihoods through provisioning services such as food, water, and raw materials (Millennium Ecosystem Assessment, 2005; MWE, 2019).

Studies across different regions show varying perceptions and uses of wetlands. In Sweden, urban communities value wetlands mainly for aesthetic, recreational, and well-being benefits (Pedersen *et al*., 2019), while in South Africa, the Zulu community links wetland conservation to tourism and local economic development (Picard, 2003). Similarly, in Saudi Arabia, wetlands are valued for irrigation, flood control, and fisheries (Al-Obaid *et al*., 2017). These examples highlight the global significance of wetlands in balancing ecological and human needs.

In contrast, African wetlands are predominantly valued for subsistence uses such as crop cultivation, fishing, and extraction of construction materials (Barakagira & de Wit, 2017; Nabahungu & Visser, 2013). In Uganda, more than 80% of people living near wetlands depend directly on them for food, water, and materials (Kakuru *et al*., 2013). However, this dependency has also driven unsustainable utilization, leading to degradation, biodiversity loss, and reduced ecological functionality (Kaggwa *et al*., 2009; Kirwan & Mudd, 2012).

Although many studies have examined wetland uses and values at national or regional scales (e.g., Kakuru *et al*., 2013; Barakagira & de Wit, 2017), limited research exists at site-specific levels such as the Masese-Budhumbuli wetland. There is inadequate documentation on how local communities perceive and utilize this urban wetland and how such interactions affect its ecological functions and plant diversity. This study therefore bridges that gap by integrating community-level insights with ecological assessments to understand how wetland use and cover changes influence plant diversity and resilience in Masese-Budhumbuli, Jinja City.

2.3 Methods of quantifying wetland use and cover changes

Wetland use and cover change refers to the transformation of various types of wetland vegetation and wetland cover resulting from the complex interactions between human activities and wetland ecosystems (Long *et al*., 2022). Accurate information on these changes is essential for environmental planning, as it improves understanding of how human activities impact wetland ecosystems and helps predict potential future alterations (Kibet *et al*., 2021; Behera *et al*., 2012). The development of earth observation satellites and advances in GIS have greatly enhanced the ability to assess wetland dynamics due to their extended temporal coverage, high spatial resolution, and broad geographic reach (Long *et al*., 2022).

Studies worldwide have applied diverse remote sensing and GIS techniques to quantify wetland changes. For example, in Dongting Lake, China, Long *et al*. (2022) used a stacking algorithm on Google Earth Engine (GEE) to detect wetland transformations over 25 years, revealing a total loss of 294.94 km^2 mainly from water bodies and reedlands. In Turkey, Berberoğlu *et al*. (2010) applied Change Vector Analysis (CVA) to Mediterranean coastal wetlands, showing that multi-spectral change detection can capture both wetland cover and condition changes. MODIS NDVI data combined with iterative classification methods have also been applied in Poyang Lake, China, to track temporal vegetation changes, though limitations arise due to the ecological complexity of wetlands (Chen *et al*., 2014; Li & Xiao, 2019).

Random Forest classifiers integrated in R (Sibanda & Ahmed, 2021) and Object-Based Image Analysis (OBIA) approaches (Hu *et al*., 2018; Dronova *et al*., 2011) have demonstrated high accuracy in urban and peri-urban wetland mapping. These studies highlight that machine learning and object-based techniques outperform traditional pixel-based methods, especially for complex or high-resolution datasets, though field validation remains critical. Supervised classification using maximum likelihood algorithms has also been applied in Kenya and China, while unsupervised NDVI/MNDWI threshold-based classifications have been used in Bangladesh (Cheruto *et al*., 2016; Bhattacharjee *et al*., 2021).

Despite this rich global literature, there is limited application of these remote sensing and GIS techniques to urban wetlands in Uganda, particularly Masese-Budhumbuli wetland in Jinja City (Namaalwa *et al*., 2013; Wasswa *et al*., 2019). Previous studies in Uganda have mostly focused on area quantification, with minimal attention to integrating temporal wetland cover changes with ecological assessments of plant diversity and wetland resilience (Isunju & Kemp, 2016; Kakuru *et al*., 2013). This study therefore applies Landsat imagery with unsupervised classification to understand historical and recent wetland use and cover changes in Masese-Budhumbuli, building on methods proven effective in other international contexts (Long *et al*., 2022; Bhattacharjee *et al*., 2021).

2.4 Drivers of wetland use and cover changes

A driver is any factor that induces a modification in an ecosystem component (MWE, 2019). Globally, wetland use and cover changes are influenced by infrastructural development, water extraction, overharvesting, land conversion, pollution, eutrophication, and the introduction of exotic species (Galatowitsch, 2018). Anthropogenic factors include conversion of wetlands for aquaculture, logging, commercial, residential, and industrial developments; drainage for agriculture; and construction of canals, dikes, dams, and levees (Millennium Ecosystem Assessment, 2005). Natural factors, such as droughts, storms, subsidence, and sea-level rise, also contribute to wetland loss and degradation (McFadden *et al*., 2007). Immediate drivers often include agricultural and urban expansion, while fundamental drivers are socio-economic and political factors such as population and economic growth (Van Asselen *et al*., 2013; Businge, 2017).

Comparative studies globally highlight region-specific drivers. In the Mekong Delta, Vietnam, wetland conversion between 1816 and 2016 was driven by population growth, urbanisation, agricultural expansion, transport network development, flood protection, overexploitation, and canal construction (Huu Nguyen *et al*., 2016). In Northeast China, marsh wetland degradation in the Honghe Reserve is primarily caused by hydrological changes driven by increased temperatures, reduced precipitation, rice cultivation, and water diversion to farms (Zhou *et al*., 2009). These examples demonstrate that both natural and human-induced factors interact to drive wetland transformation worldwide.

In Uganda, wetland degradation is primarily driven by population pressure, land scarcity, and the perception of wetlands as exploitable land (Barakagira & Kateyo, 2008; UBOS, 2024). Between 1980 and 2014, Uganda's population increased by 22.2 million, significantly raising demand for land, water, and other resources, which has accelerated wetland encroachment and degradation (MWE, 2019). Overexploitation of wetland resources including water for domestic and irrigation use, papyrus and grasses for crafts and fodder, and soils for cultivation has been reported across western and central Uganda (Businge, 2017; MWE, 2019).

Pollution and waste disposal are also critical drivers. Petroleum-derived compounds, plastics, insecticides, and industrial effluents contaminate wetlands, while communities frequently dispose of rubbish directly into wetland areas (Namaalwa *et al*., 2013; Khan *et al*., 2020). Many synthetic chemicals persist in wetlands due to slow decomposition (Alshehrei, 2017). Additionally, annual bush fires, common in East Africa to clear land for agriculture and grazing, contribute to wetland degradation in Uganda, affecting wetlands such as Mpologoma, Bisina, Namatala, Malaba, Opeta, Manafwa, Doho, Kibimba, and Awoja (Businge, 2017; Kamau & Medley, 2014; MWE, 2019).

Agricultural expansion, particularly for sugarcane and crop cultivation, has been identified as a major driver of wetland loss in the Lake Victoria basin (J *et al*., 2010; Fischer & Lamey, 2018). In Nakivubo wetland, Kampala, 62% of vegetation was lost between 2002 and 2014 due to crop cultivation, population pressure, and poor governance (Isunju & Kemp, 2016). Similarly, the Kampala-Mukono Corridor lost approximately 47% of wetlands from 1974 to

2013, driven by urbanization, industrial development, poverty, and political interference (Wasswa *et al*., 2019). Drivers of change in other Ugandan wetlands, including Namatala and Myoma wetlands, include river diversion, limited arable land, food demand, pollution, waste disposal, lack of alternative livelihoods, and inadequate enforcement of wetland policies (Namaalwa *et al*., 2013; Kanyunyuzi, 2022).

While these studies highlight widespread drivers across Uganda, there is limited site-specific research on Masese-Budhumbuli wetland. Understanding the localized drivers, particularly in urban wetlands exposed to industrial, agricultural, and infrastructural pressures, is crucial for developing effective management strategies that balance ecological protection with community livelihoods.

2.5 Plant species diversity in wetlands

Plant species diversity refers to the variety of plant species within an ecosystem and the relative abundance of each species (Vasilevich, 2009). In wetlands, plant diversity is essential for maintaining ecological functions, stabilizing hydrology, supporting nutrient cycling, carbon sequestration, and providing habitats for faunal species, which collectively underpin ecosystem resilience (Zedler & Kercher, 2005; Mitsch *et al*., 2015). Beyond ecological functions, the diversity of wetland plants can attract tourism, support recreation, and generate revenue for local communities (Aazami & Shanazi, 2020). Moreover, plant diversity influences the wetland's capacity to filter sediments, absorb pollutants, and regulate water quality, which is particularly important in wetlands connected to Lake Victoria (Kaggwa *et al*., 2009; John & Aloyce, 2018).

Comparative studies across different regions demonstrate the variation in wetland plant communities. In South Africa, Du Toit *et al*. (2021) recorded 102 plant species in the former Tlokwe Municipal area, with dominant species including Cyperus longus, Paspalum dilatatum, and Leersia hexandra. In Northwestern China, Li *et al*. (2007) identified dominant species such as Phragmites communis, Kalidium foliatum, and Nitraria tangutorum. In Pakistan, 282 vascular wetland plant species were recorded in Mardan division, predominantly herbs (Khan *et al*., 2022). In Ethiopia's Kedar-Besaso wetland, only 20 species from 14 families were recorded, with low Shannon diversity (H = 1.15) and uneven distribution (E = 0.385) (Abdulmalik *et al*., 2022).

In Uganda, wetland plant diversity varies considerably across sites, reflecting differences in hydrology, land use, and anthropogenic pressure. In Lubigi wetland, dominant macrophytes include *Cyperus papyrus*, *Echinochloa pyramidalis*, *Typha capensis*, *Rottboellia cochinchinensis*, and *Oldenlandia lancifolia* (John & Aloyce, 2018). Kalema & Ssegawa (2007) documented 208 species in Nyamuriro wetland and 184 species in Doho wetland, with dominant species such as *Cyperus papyrus*, Leersia hexandra, and Cayratia ibuensis. These studies highlight that anthropogenic pressures such as agriculture, urban expansion, and industrial activities can lead to shifts in species composition, favoring disturbance-tolerant or invasive species, which reduces functional diversity and ecological resilience (Namaalwa *et al*., 2013; Wasswa *et al*., 2019).

Despite the recognized ecological and socio-economic importance of wetland plant diversity, there remains limited site-specific research in urban and peri-urban wetlands, particularly Masese-Budhumbuli wetland in Jinja City. This wetland is exposed to pressures including industrial effluents, agricultural encroachment, and urban expansion, which threaten its plant communities and the ecosystem services they provide. Documenting plant species richness, composition, and abundance in Masese-Budhumbuli wetland is therefore critical for understanding ecological integrity, identifying conservation priorities, and informing sustainable management strategies for both biodiversity and local livelihoods.

2.6 Ecological resilience of ecosystems to disturbances

Ecological resilience has been defined as the amount of change required to shift an ecosystem from one set of structures and processes to another, or the amount of disturbance a system can withstand before moving into an alternative stable state (Chambers *et al*., 2020). In applied contexts, resilience describes the capacity of an ecosystem to regain its fundamental structure, processes, and functioning or remain largely unchanged despite stresses and disturbances (Seidl *et al*., 2016).

One important factor in determining how management actions should be structured is the ecological resilience of the system, which provides insights into the ease or difficulty of transitions between states (Gunderson, 2000). Assessing ecological resilience in wetland ecosystems is particularly important because wetlands are highly dynamic and sensitive to both anthropogenic and natural disturbances, such as land use changes, invasive species, pollution, and hydrological alterations (Mitsch *et al*., 2015; Baho *et al*., 2017). Evaluating resilience at the landscape level offers decision-makers a comprehensive understanding of system dynamics and the potential consequences of multiple stressors (Torrico & Janssens, 2010). Management strategies for degraded ecosystems may include restoration to a desired state, allowing natural recovery, or adapting to altered conditions when full recovery is no longer feasible (Gunderson, 2000).

Assessing ecological resilience is challenging due to the intrinsic complexity of ecosystems and the interactions among biotic, abiotic, and socio-economic factors (Baho *et al*., 2017). Various methods have been developed to quantify resilience. Torrico & Janssens (2010) evaluated resilience in the Atlantic Rainforest, Brazil, using eco-volume, bio-volume, and resilience indices, finding that natural and silvo-pastoral systems exhibited higher resilience than intensive cattle or vegetable systems. Bradford *et al*. (2019) employed a daily time-step, process-based ecosystem water balance model to evaluate soil moisture and temperature regimes in arid regions of western North America, noting limitations of these measures under extreme events.

In China, Zhang *et al*. (2020) used multi-criteria decision analysis (MCA) with indicators including digital elevation, rainfall, soil organic carbon, GDP, and ecosystem service value, revealing spatial variation in ecological resilience, with higher resilience in southern regions and lower resilience in northern areas. Cushman & McGarigal (2019) applied dynamic landscape simulation (RMLands) and landscape structure metrics (e.g., contagion index, patch size) to quantify resilience in western Montana and northern Idaho, USA, linking historical disturbance regimes to current ecosystem stability.

For wetland ecosystems, ecological resilience is closely tied to plant species diversity, hydrological stability, and the capacity to recover from disturbances such as agricultural encroachment, industrial pollution, and invasive species (Zedler & Kercher, 2005; Mitsch *et al*., 2015). High plant diversity supports functional redundancy, meaning that multiple species can perform similar ecological roles, which ensures the persistence of key ecosystem processes such as nutrient cycling, sediment filtration, water purification, carbon sequestration, and habitat provision for wildlife (Elmqvist *et al*., 2003; Hooper *et al*., 2005; Opitz *et al*., 2021).

Furthermore, resilient wetlands contribute to socio-economic well-being by sustaining fisheries, supporting small-scale agriculture, supplying medicinal plants and building materials, and providing flood regulation for local communities (Millennium Ecosystem Assessment, 2005; Kakuru *et al*., 2013).

Conversely, degraded wetlands with low plant diversity are less resilient, more vulnerable to invasion by alien species, and may experience altered biogeochemical cycles, reduced water quality, and diminished ecosystem service provision (Namaalwa *et al*., 2013; Wasswa et al., 2019). Such degradation not only threatens biodiversity but also undermines the livelihoods of communities that rely on wetland resources, increases vulnerability to flooding and drought, and may contribute to eutrophication and sedimentation in adjacent water bodies, such as Lake Victoria (MWE, 2019; Opitz *et al*., 2021).

In this study, multi-criteria decision analysis (MCA) was employed to quantify the ecological resilience of plant communities in Masese-Budhumbuli wetland, Jinja City. MCA was selected for its ability to evaluate trade-offs among multiple indicators, incorporating both ecological and anthropogenic drivers of resilience. The indicators used included temperature, precipitation, soil moisture, level of infrastructure development, NDVI, Normalized Burn Ratio (NBR), and Fraction of Absorbed Photosynthetically Active Radiation (FAPAR). However, the application of MCA in this study has limitations**:** it relies on available biophysical and remotely sensed data, which may not fully capture fine-scale ecological interactions, species-specific responses, or local knowledge of wetland use. Moreover, while MCA provides a composite resilience score, it does not account for long-term adaptation potential of plant communities or the cumulative impacts of repeated disturbances, potentially underestimating the wetland's true resilience capacity. Integrating these indicators enables the assessment of both vegetation health and landscape susceptibility to human and environmental pressures, providing a robust framework to guide wetland management and restoration planning.

2.7 Conceptual framework

Masese-Budhumbuli wetland has a variety of plant species for example papyrus, typha, phragmites and miscathedium (Ruffins, 2015). The wetland vegetation and other wetland biodiversity provide a range of values to communities and the environment. Some of the values provided by the wetland include water purification, flood control, climate modification, carbon sequestration and air quality regulation among others (Millenium Ecosystem Assessment, 2005) as shown in Figure 2.1. The communities living adjacent to the wetland also use it for various purposes such as farming, fishing, grazing, hunting, and harvesting of water, firewood, craft and construction materials (Turyahabwe, Kakuru *et al*., 2013). The unsustainable utilisation of the wetland by the adjacent communities leads to changes in wetland use/cover types (Barakagira & De Wit, 2019). Other drivers of wetland use and cover changes include population increase, bush burning, political interference, waste disposal and infrastructural development (Barakagira & Kateyo, 2008; Businge, 2017). The wetland use and cover changes have important implications on the hydrological regime of the wetland, the wetland biodiversity, land, the atmosphere and various services provided by the wetland, although some plants are resilient to the changes in wetland use/cover types (Dean *et al*., 2018; Mao *et al*., 2018).

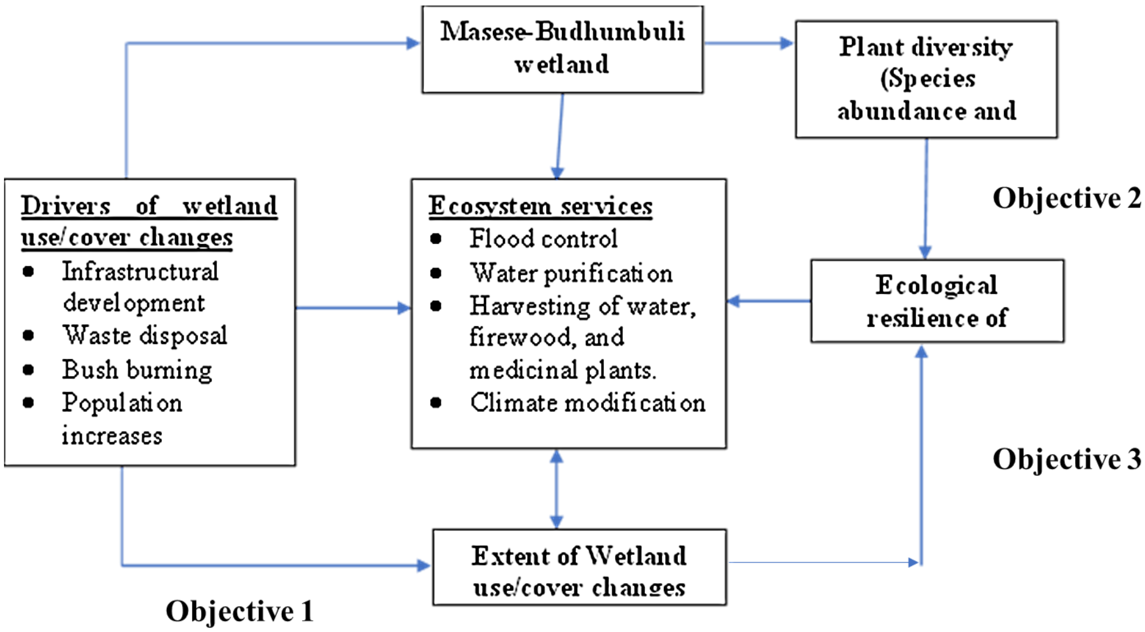

Figure 2. 1. Conceptual framework of the study

CHAPTER THREE: MATERIALS AND METHODS

3.1 Introduction

This section provides a detailed description of the research design, study area, data collection methods, and analytical approaches employed to investigate wetland use, cover changes, plant diversity, and ecological resilience in Masese-Budhumbuli wetland, Jinja City. It outlines the systematic procedures for sampling, remote sensing and GIS analyses, socio-economic surveys, and ecological assessments. The chapter also explains the rationale for selecting specific quantitative and qualitative methods, as well as the techniques used to integrate community-level insights with ecological data, ensuring a comprehensive understanding of the interactions between human activities and wetland ecosystems.

3.2 Description of the study area

3.2.1 Location

Masese-Budhumbuli wetland is found in Jinja City, Eastern Uganda, at the peripheral of Lake Victoria (**Figure 0.1**). Administratively, the wetland is located in-between Jinja South Division and Jinja North Division. The wetland covers a total area of 213.6 hectares. The coordinates of the wetland are 526393.69E, 50462.90N. Masese-Budhumbuli wetland was selected because it is facing pressure from land use changes, making it ideal for studying urban-wetland interactions.

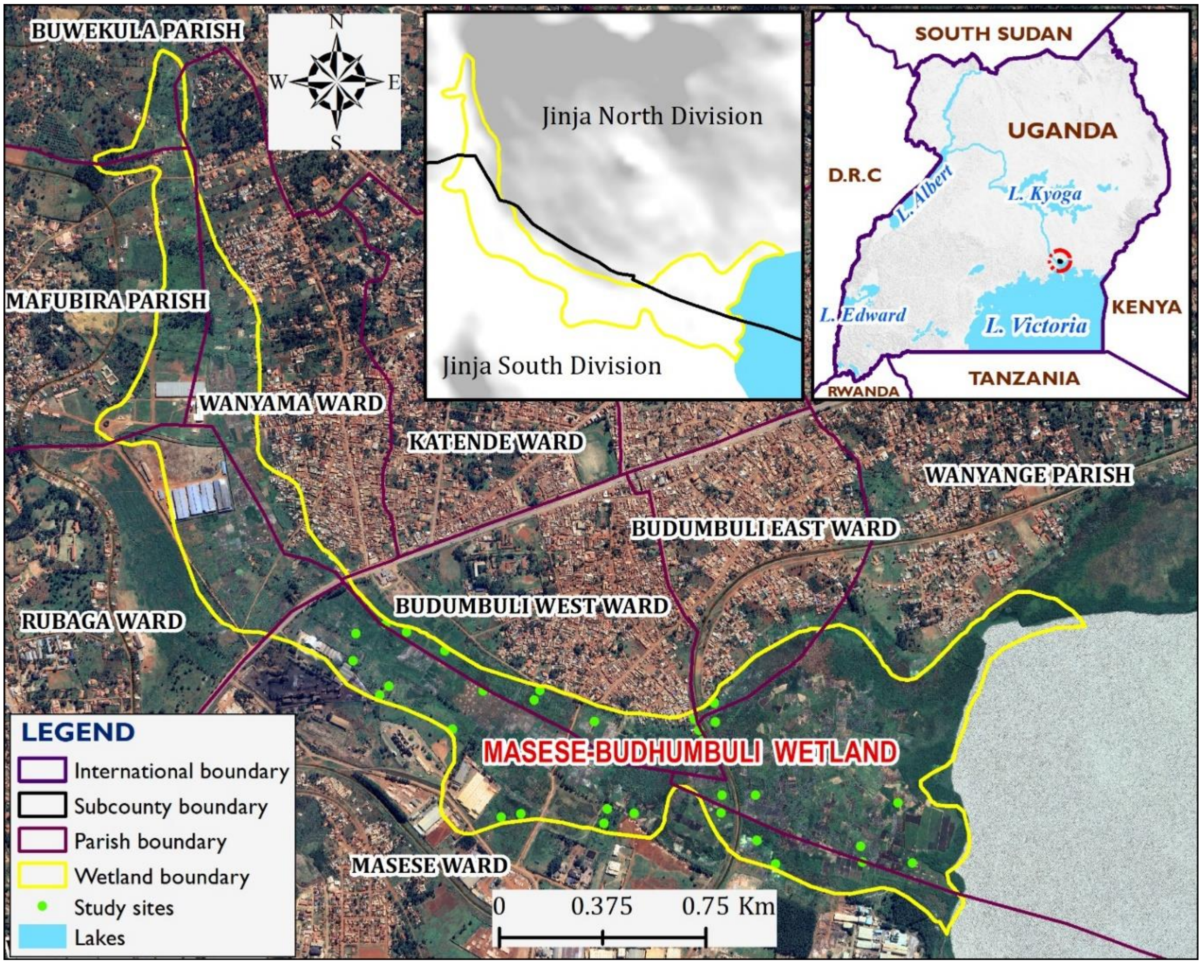

Figure 0.1: Location of Masese-Budhumbuli wetland in Jinja City, Eastern Uganda

3.2.2 Climate

The area experiences a tropical climate with two rainfall seasons in the months of March-May and September-November (Munabi *et al*., 2009). However, the rainfall patterns have changed in the past years, resulting in less clearly defined rainy seasons (Lindsay *et al*., 2004). The area receives annual rainfall of about 1,260mm and warm temperatures that range between 23^oC and 32^oC (Namuhani & Cyrus, 2015).

3.2.3 Vegetation and land use

The vegetation types in Masese-Budhumbuli wetland include papyrus, grasslands and woodlands whereas the major land use types in the wetland include croplands and built-up areas (MWE, 2019). The most dominant land use/cover type in the wetland is croplands (54.2%) followed by papyrus and floating vegetation (35%) (MWE, 2019).

3.2.4 Topography, soils and drainage

The altitude in Masese-Budhumbuli wetland is relatively flat with elevation ranging between 1,134 and 1,169 metres above sea level. The soils in the wetland are characterized by dark red clays, and are sometimes underlain by laterite (Namuhani & Cyrus, 2015). Kikenyi and Walumbe rivers drain through Masese-Budhumbuli wetland and eventually to Lake Victoria.

3.2.5 Socio-demographic characteristics

The study population included communities living adjacent to Masese-Budhumbuli wetland. The wetland is surrounded by 8 parishes (Budhumbuli East, Budhumbuli West, Wanyama, Buwekula, Mafubira, Wanyange, Masese and Rubaga) with a total population of 107,694 people and 27,612 households (UBOS, 2024). The average population density in each parish is 1,566 persons per square kilometer. The sources of livelihood in the adjacent communities include employment income, business enterprise, livestock rearing, fish farming, crop farming, property income and transport services (Taxi operation/ *Boda-boda* riding) among others (UBOS, 2024). The major crops grown in the wetland include rice, maize, yams, and cabbage.

3.3 Research Design and Sampling Procedure

3.3.1 Sampling of wetland plant species

A systematic random sampling design was adopted to assess the wetland plant species diversity. This involved the use of plots that were laid on transect lines. The sampling of wetland vegetation followed protocols by (Little, 2013; Abdulmalik *et al*., 2022). Transect lines of 1km and plots of 10m x 20m were established in the study area. The first plot on the transect line was randomly established, and after every 50m, an alternating plot was established. The 50 m interval was selected to capture spatial variability in plant species composition while minimizing redundancy and ensuring efficient, representative sampling. The process of alternating plots along the transect line was repeated up to the end of the transect line. In total, 25 transects were laid out, covering an estimated 5 hectares of the wetland to ensure adequate spatial representation of vegetation. Within each sample plot, nesting was done (Error! Reference source not found.) to capture the different plant species. The dimensions of the nested plots included;

- 10m x 20m for trees with a dbh of more than 10cm
- 10m x 10m for shrubs and saplings with the diameter at root collar (drc) of 5-10cm
- 5m x5m for herbs and shrubs with the drc of less than 5cm
- 1m x1m for herbs and grasses

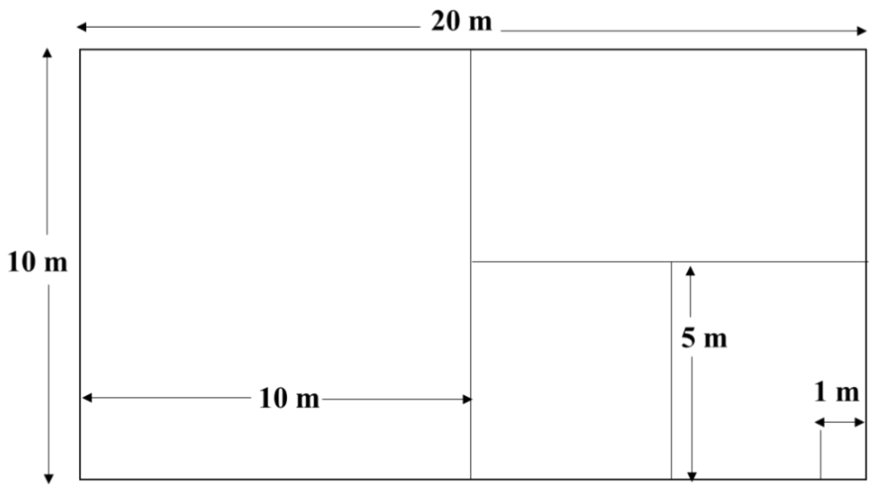

Figure 3. 1: Plot layout

A hand-held Garmin Global Positioning System (GPS) of 3m accuracy was used for locating the position of the plots. A compass was used to determine the direction of the transect line and plots. The pegs, coloured ropes and coloured ribbons were used for marking the plot boundaries. A tape measure was used to determine the interval distances along the transect line and the distance of the plots. A diameter tape was used to measure the diameter at breast height (dbh) for big trees. The Vanier calliper was used to record the dbh of moderate-sized as well as the diameter at root collar (drc) for shrubs and herbs. The plant press was used to store the plant parts for identification.

3.3.2 Household sampling

The study employed a simple random sampling approach to select respondents for administering the household questionnaire (Appendix 2). The merits of simple random sampling include the possibility of generalizing about the population, ease of use, and accuracy of representation (Mohsin, 2016; Sharma, 2017).

Masese-Budhumbuli wetland is located in Jinja City, Eastern Uganda. Jinja City has two divisions i.e., Jinja North Division and Jinja South Division. One division, i.e., Jinja North Division, was randomly selected to conduct household sampling. Jinja North division has fifteen parishes and six of them are crossing the study wetland. Random sampling of households was done in the 6 parishes that cross the wetland. This is because communities living adjacent to wetlands are highly knowledgeable and possess important information, such as the ecosystem services of the wetlands and the drivers of degradation, due to their daily interactions with them (Drăghici *et al*., 2017). Among the six parishes intersecting the study wetland, four were selected for household sampling. The selection was carried out randomly using a lottery method to ensure each parish had an equal chance of inclusion. The selected parishes were Mafubira, Buwekula, Budumbuli West, and Wanyange. Within each of the selected parish, two villages were also randomly selected to conduct the household sampling of respondents. The selection of respondents was done using random numbers with the assistance of the chairman LC1 and the parish chief. The village registration list was used as a sampling frame.

The four selected parishes have a total of 15,047 households (UBOS, 2024). Therefore, using the Krejcie & Morgan (1970) formula for sample size determination (Equation 1), a total of 377 households was sampled around Masese-Budhumbuli wetland.

$s = X^2 NP (1 - P) \div d^2(N - 1) + X^2P (1 - P)$……………………………………………Equation 1

where;

s is the required sample size, X^2 is the table value of chi-square for 1 degree of freedom at the desired confidence level (3.841), N is the population size, P is the population proportion (assumed to be .50 which should provide the maximum sample size), and d is the degree of accuracy expressed as a proportion (.05).

3.4 Data collection methods

3.4.1 Satellite Images

The satellite images for the study area that have a reduced cloud cover (less than 10%) and were captured in the dry months of January and February, were downloaded from the Earth Explorer website (https://earthexplorer.usgs.gov/). For consistency in image resolution, satellite images captured by the same sensor (Landsat) were downloaded. The satellite images were downloaded for four years at an interval of 10 years, i.e., 1993, 2003, 2013 and 2023. The 10-year interval was selected to effectively capture long-term trends and decadal variations in wetland use and cover changes, while minimizing data redundancy from short-term fluctuations. The year 1993 was chosen as the baseline because it represents the earliest period with consistent and cloud-free Landsat data (Landsat 5 TM) suitable for multi-temporal analysis in Uganda. This timeframe allows for the assessment of both historical and recent transformations in the Masese-Budhumbuli wetland, reflecting changes over three decades of increasing human activity and urban expansion in Jinja City. A period of more than five years was recommended for analysis of wetland changes (Davidson, 2014).

3.4.2 Plant Species data

The coverage of herbs in plots of 1m*1m was visually estimated as herbs are a key component of wetland plant diversity and provide important indicators of ecosystem health and resilience. The diameter at breast height (dbh) of trees and the diameter at root collar (drc) for the shrubs and herbs were read from the Vanier caliper. The data obtained per plot was recorded on the data collection sheet (Appendix 1). The plant species that were not identified from field, were collected, pressed and transported to the Makerere University Herbarium for identification.

3.4.3 Household Interviews

Cross-sectional household interviews were conducted using a semi-structured questionnaire (Appendix 2) to understand the drivers of wetland use and cover changes and the plants that are resilient to disturbances. A total of 377 households were sampled from the four parishes (Mafubira, Buwekula, Budhumbuli West, and Wanyange) surrounding Masese-Budhumbuli wetland, using simple random sampling from the village registration lists with the guidance of the LC1 Chairman and parish chief. Within each selected village, households were randomly selected using random numbers, and the questionnaire was administered face-to-face to the household head, or, in their absence, to the eldest adult decision-maker. This is because it is such people who have stayed in the area for a longer time and therefore may have a deeper understanding of issues concerning wetlands.

Table 3. 1. The distribution of the sampled households was proportional to the number of households in each parish (UBOS, 2024)

Parish	Total Households	Sampled Households
Mafubira	4,200	118
Buwekula	3,850	108
Budhumbuli West	3,500	98
Wanyange	3,497	53
Total	15,047	377

3.4.4 Key Informant Interviews

Twelve key informant interviews were also conducted to gain a deeper understanding of the drivers of wetland use and cover changes and the plants that are resilient to disturbances. The key informants were purposively selected based on their knowledge of wetland issues. Some of the key informants included the chairperson of the environmental committee for the village or wetland, the district natural resources officer, the district wetlands officer, and stakeholders from the wetlands management department, the Ministry of Water and Environment, the National Environment Management Authority and the International Union for Conservation of Nature. The key informants were interviewed using a key informant guide (Appendix 3).

3.4.5 Focus Group Discussions (FGDs)

FGDs were also held with leaders and residents in the villages surrounding the Masese-Budhumbuli wetland to further obtain in-depth information and knowledge on the drivers of wetland use and cover changes, as well as the plants that are resilient to disturbances. The FGDs consisted of 6-12 discussants who are involved in the use of the wetland resources and those deemed well conversant with the wetland. Participants in the FGDs were purposively selected based on their duration of stay around the wetland, specific wetland uses, knowledge of wetland uses, and involvement in wetland management (Twongyirwe *et al*., 2018). At least two (2) FGDs were conducted in the villages surrounding Masese-Budhumbuli wetland. The FGDs were conducted using a focus group discussion guide (Appendix 4).

3.5 Data Analysis

3.5.1 Examining the extent and drivers of wetland use and cover changes in Masese-Budhumbuli wetland

The boundary of Masese-Budhumbuli wetland was obtained from the Wetlands Management Department, Ministry of Water and Environment. The wetland boundary was used to mask the satellite images. Prior to image classification, radiometric correction, digital filtering and composite generation were done on the raw satellite images to generally improve the image interpretation process (Pons *et al*., 2014). The processed satellite images were classified using the unsupervised image assessment technique in order to extract information from the images based on the spectral signatures. Using ArcGIS 10.5, the extracted spectral classes were reclassified into seven wetland use/cover types, and these included built-up, grasslands, farmlands, papyrus, open water, tree plantations, and woodlands as described in Table 3.2 below.

Table 3. 2. Description of the wetland use/cover classes mapped in Masese-Budhumbuli wetland

Land use/cover types	Description
Built-up	These are wetlands converted into settlements, industries, waste treatment plants, roads, etc.
Grasslands	These are wetlands characterized by tall and short grasses.
Farmlands	These are wetlands under cultivation with crops such as yams, maize, rice, etc.
Papyrus	These are wetlands with rooted and floating vegetation that can grow up to 5-6m.
Open water	These are areas with natural and man-made open water bodies.
Tree plantations	These are wetlands planted with trees such as pine and eucalyptus.
Woodlands	These are wetlands composed of scattered tall trees, shrubs, and palm trees with grasslands underneath.

Additional datasets such as ground-truthed data, Google Earth images, and the national wetland use/cover map (2021) were used to validate the accuracy of the classified satellite images. Ground-truth points were picked from the field using a hand-held Global Positioning System (GPS). An error matrix was computed to assess the correlation between the classified wetland use/cover types and the ground land use/cover types. From the matrix, the producer's accuracy, the user's accuracy, error of omission, error of commission and the overall accuracy of the image classification were calculated. A change detection analysis was carried out to determine the wetland use and cover changes between the different years in the study area. A land-use transition matrix was used to quantify the changes in terms of losses and gains in each land use/cover type over the study timeframe.

Analysis of variance (ANOVA) was used to assess the significance of changes in wetland use and cover types. The test was applied to determine whether the mean cover changes varied significantly across the four time periods (1993, 2003, 2013, and 2023). The method was considered appropriate because the data comprised continuous measurements of wetland cover areas derived from classified satellite imagery and systematic sampling plots. The total sample size varied by cover type, ranging from approximately 13,700 observations for open water to 334,000 for farmlands, corresponding to the number of spatial data points (pixels or plot records) analyzed across the study periods. This large sample size strengthened the statistical power of the ANOVA and provided robust evidence that the observed changes in wetland use and cover were statistically significant (p<0.05).

Descriptive statistics (frequency, mean and standard deviation) and Friedman test were used to understand the different drivers of wetland use and cover changes in Masese-Budhumbuli wetland. Descriptive statistics (frequency, mean, and standard deviation) and the Friedman test were employed to analyze the different drivers of wetland use and cover changes in the Masese-Budhumbuli wetland. The Friedman test, a non-parametric alternative to the one-way repeated measures ANOVA, was used to determine whether statistically significant differences existed in the mean ranks of the perceived drivers of wetland change. The test was appropriate because respondents rated multiple potential drivers on a five-point Likert scale, generating ordinal data suitable for ranked comparison. For each respondent, ratings were ranked across all drivers, and the resulting mean ranks were compared using the Chi-square (χ^2) distribution. A significance level of $p < 0.05$ was used to determine whether variations among the drivers were statistically significant.

The data from key informant interviews and focus group discussions about wetland drivers were analyzed through thematic and content analysis. This involved organizing texts in respective contexts, coding, developing themes, transcribing and then data analysis (Castleberry & Nolen, 2018). The results were then integrated with quantitative analyses, that is the Friedman test of ranked drivers (Table 4.5), to provide a comprehensive understanding of the major factors influencing wetland use and cover changes. The statistical analyses were performed using IBM SPSS v20.

3.5.2 Determining the effect of wetland use and cover changes on plant species abundance and richness in Masese-Budhumbuli wetland

A Kolmogorov-Smirnov test was used to test for normality of the data in the different plots.

The plant species diversity in Masese-Budhumbuli wetland was computed as species richness, Shannon-Weiner diversity index and Shannon-Weiner Evenness Index (Romano *et al*., 2001). Species richness was considered as the total number of plant species (Holec *et al*., 2020). The Shannon-Weiner diversity index (H^I) was calculated from the following formula;

Shannon-Weiner diversity index, $H^I = - \sum P_i ln P_i$

where P_i is the proportional abundance for each species

The evenness of plant species in Masese-Budhumbuli wetland was computed using the Shannon-Weiner Evenness Index (*E*), which is given by the following formula;

Shannon-Weiner Evenness Index, $E = \frac{H^I}{H^I_{max}}$

where H^I is the Shannon-Weiner diversity index and H^I_{max} is the natural logarithm of species richness (S). The Shannon-Weiner Diversity Index (H′) is appropriately used because it accounts not only for species richness (the total number of species) but also for species evenness how evenly individuals are distributed among those species (Romano *et al*., 2001).

A one-way Analysis of Variance (ANOVA) was used to determine the effect of wetland use and cover changes on plant diversity in Masese-Budhumbuli wetland. The dataset, comprising plant diversity metrics collected from 112 sampled plots, was analyzed using ANOVA followed by post-hoc Tukey Honest Significant Difference (HSD) tests to identify specific wetland cover changes that significantly influenced plant diversity. The statistical analyses were performed using R. Studio v. 9.

3.5.3 Determining the ecological resilience of plants to wetland use and cover changes in Masese-Budhumbuli wetland

The multi-criteria decision analysis model was used to assess the ecological resilience of plants in Masese-Budhumbuli wetland. The model uses multiple criteria as the basis for assessment, and ranks known alternatives according to the preference structure expressed by decision makers (Zhang *et al*., 2020). The indicators that were used to assess the ecological resilience of plants included temperature, precipitation, soil moisture, level of infrastructure development, Normalized Difference Vegetation Index (NDVI), Normalized Burn Ratio (NBR) and the Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) (Table 3.3).

Table 3. 3 Indicators used to assess the ecological resilience of plants in Masese-Budhumbuli wetland

Indicator	**Source**	**Reference**
Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)	Copernicus Global Land Service	(Yi & Jackson, 2021)
Level of infrastructure development	Wetland use/cover classification	(Zhang et al., 2020)
Normalized Burn Ratio (NBR)	Satellite Image	(Yi & Jackson, 2021)
Normalized Difference Vegetation Index (NDVI)	Satellite Image	(Yi & Jackson, 2021)
Annual Precipitation	Modern-Era Retrospective Analysis for Research and Applications (NASA)	(Wu & Liang, 2020; Zhang et al., 2020)
Soil moisture	Harmonized World Soil Database (FAO)	(Bradford et al., 2019; Wu & Liang, 2020)
Mean Annual Temperature	Modern-Era Retrospective Analysis for Research and Applications (NASA)	(Wu & Liang, 2020)

The Normalized Burn Ratio (NBR) and the Normalized Difference Vegetation Index (NDVI) were calculated according to Yi & Jackson (2021), using the following formula;

$$\text{NBR} = \frac{\text{NIR}-\text{SWIR}}{\text{NIR}+\text{SWIR}}$$

$$\text{NDVI} = \frac{\text{NIR}-\text{R}}{\text{NIR}+\text{R}}$$

where NBR is the Normalized Burn Ratio, NIR is the Near Infrared band, SWIR is the Short Wave Infrared band, R is the Red band, and NDVI is the Normalized Difference Vegetation Index.

The above data was obtained from different sources, which means that it had different attributes and dimensionality. Therefore, the differences in data types between indicators were eliminated, and they were converted into dimensionless data. The study employed the range transformation method to standardize the assessment indicators. The range method was used to effectively normalise the original data between [0, 1] to make the dispersion of the indicators consistent. The standard formula of the range method is shown below;

$$\text{P} = \frac{\text{MAX}-\text{Xi}}{\text{MAX}-\text{MIN}}$$

where MAX is the maximum value of all indicator data before standardisation, MIN is the minimum value of all indicator data before standardisation, Xi is the value of the ith data point before standardisation, and P is the indicator value obtained after standardisation.

After standardizing the indicators, the weights were determined using the entropy method. The concept of entropy is derived from thermodynamics in physics and reflects the degree of disorder or variability in a system (Jakimowicz, 2020). In this context, entropy measures the amount of information each indicator provides across the study area. Indicators with greater variability, such as level of infrastructure development, contribute more information and are therefore assigned higher weights, whereas indicators with lower variability, such as mean annual temperature, are considered less informative and receive lower weights. Entropy has been widely applied in research fields such as sustainable development and socio-economics to objectively assess the relative importance of variables (Wang *et al.*, 2022). This method ensures that each ecological resilience indicator contributes appropriately to the overall assessment of the Masese-Budhumbuli wetland. Table 3.4 shows the weights that were assigned to the different ecological resilience indicators.

Table 3. 4. Weights assigned to the different ecological resilience indicators

Ecological Resilience Indicator	**Weight**
Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)	0.142521
Level of infrastructure development	0.163836
Normalized Burn Ratio (NBR)	0.140331
Normalized Difference Vegetation Index (NDVI)	0.140094
Annual Precipitation	0.135304
Soil Moisture	0.142655
Mean Annual Temperature	0.13526

After assigning the weights to the standardized indicators, the assessment indicators were then classified to categorize the level of ecological resilience in Masese-Budhumbuli wetland. The classification was done using the natural breakpoint method in ArcGIS 10.5. The method utilizes discontinuities in the dataset as the basis for classification. The data interval divided by the natural breakpoint method has the characteristics of the smallest intra-class difference and the largest inter-class difference, which can be used as a scientific basis for the division of levels of ecological resilience (Zhang *et al*., 2020). The classified levels of ecological resilience were categorized into very low, low, moderate, high and then very high.

A Pearson correlation coefficient was used to assess the relationship between the ecological resilience of plants and wetland use and cover changes in Masese-Budhumbuli wetland, Jinja City. The statistical analyses were performed using R. Studio v. 9.

CHAPTER FOUR: RESULTS

4.1 Introduction

This section presents the study findings on wetland use, cover changes, plant species diversity, and ecological resilience in Masese-Budhumbuli wetland, Jinja City, using tables, figures, and descriptive summaries.

4.2 Extent and drivers of wetland use and cover changes in Masese-Budhumbuli wetland, Jinja City

Results for the changes in wetland extent and drivers of wetland use and cover changes in Masese-Budhumbuli wetland are presented and interpreted, providing insights for sustainable management.

4.1.1 Extent of wetland use and cover changes (1993, 2003,2013 and 2023)

The classification of satellite images revealed six wetland use/cover types in Masese-Budhumbuli wetland, i.e., built-up, farmlands, grasslands, papyrus, open water, and tree plantations. The most dominant wetland cover type in 1993, 2003, and 2013 was papyrus, whereas in 2023, farmlands dominated the wetland (Table 4.1). The least dominant wetland use/cover type in all the years of analysis is open water. Table below shows the coverage of wetland use/cover types in 1993, 2003, 2013, and 2023.

Table 4. 1 Coverage of wetland use/cover types in Masese-Budhumbuli wetland in 1993, 2003, 2013 and 2023

Wetland Use & Cover Types	**1993** Area (Ha)	%	**2003** Area (Ha)	%	**2013** Area (Ha)	%	**2023** Area (Ha)	%
Built-up	1.1	0.5	1.8	0.8	3.6	1.7	17	8
Farmlands	31	14.5	53	24.8	80.4	37.6	102	47.8
Grasslands	80	37.5	62.4	29.2	35.4	16.6	42.2	19.8
Open water	0.5	0.3	0.5	0.3	0.6	0.3	3.1	1.5
Papyrus	99.5	46.6	93.5	43.8	90.1	42.2	43.7	20.4
Tree plantations	1.4	0.7	2.4	1.1	3.5	1.7	5.6	2.6
Total	**213.6**	**100**	**213.6**	**100**	**213.6**	**100**	**213.6**	**100**

The change analysis between the different years showed that built-up, farmlands, open water and tree plantations increased between 1993 and 2023 (Figure 4.1). The grasslands were observed to increase during the 2013 to 2023 period. Papyrus decreased between 1993 and 2023 while grasslands decreased between 1993 and 2013. Most of the changes in wetland use/cover types were observed between 2013 and 2023. However, the biggest increase in farmlands and a decrease in grasslands occurred during the 2003 to 2013 period. Most of the increase in built-up, open water, tree plantations, and grasslands; and the biggest decrease in papyrus was observed between 2013 and 2023. Figure 4.1 below shows the changes in the coverage of wetland use/cover types between 1993 and 2023.

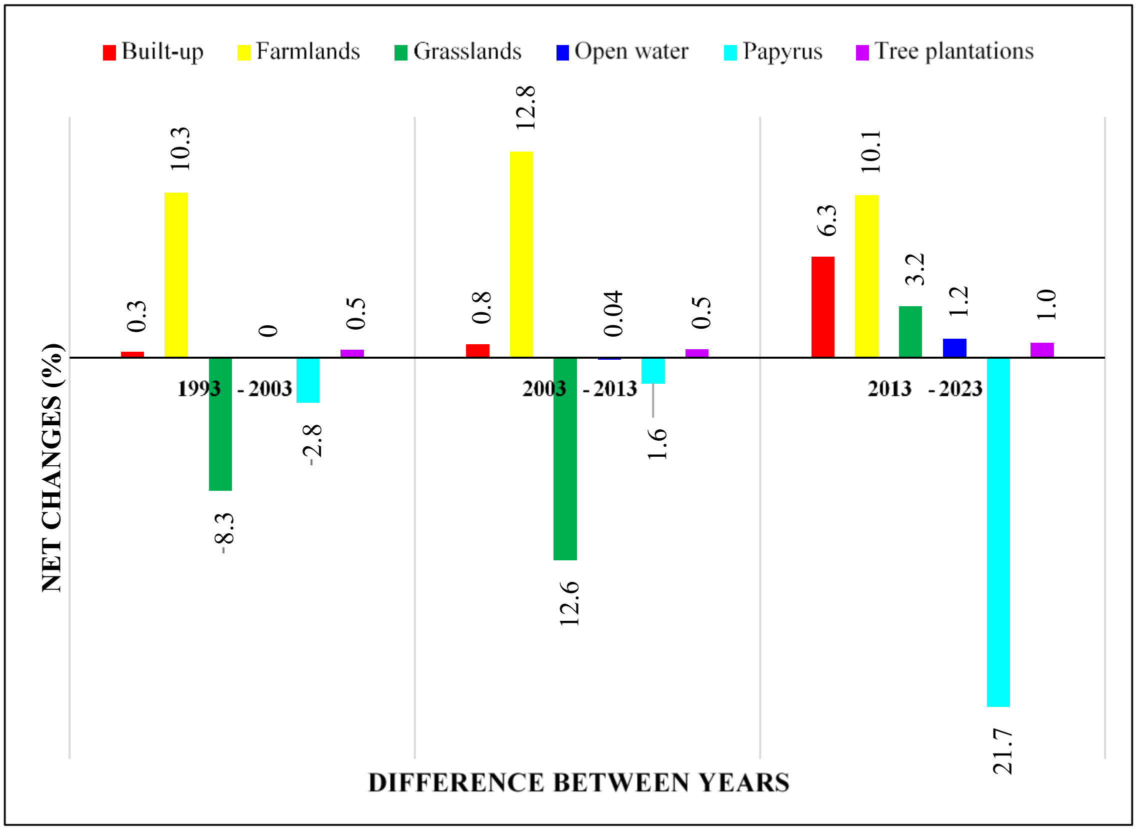

Figure 4. 1. Changes in the coverage of wetland use and cover types between 1993 and 2023

Spatially, the farmlands intensified within the wetland in 2003 and 2013, and by 2023, they had replaced the papyrus in the southern part of the wetland (Figure 4.2). Similarly, the built-up areas in the form of roads, industries, and settlements intensified inside and at the fringes of the wetland, and by 2023, these had spread to most parts of the wetland. The tree plantations were also vividly seen to increase in the northern part of the wetland, especially in 2013 and 2023. The grasslands that were spread to most parts of the wetland in 1993 were seen to have reduced by almost 50% in 2013 and 2023. Minimal increments in open water were also seen in the southern part of the wetland in 2023.

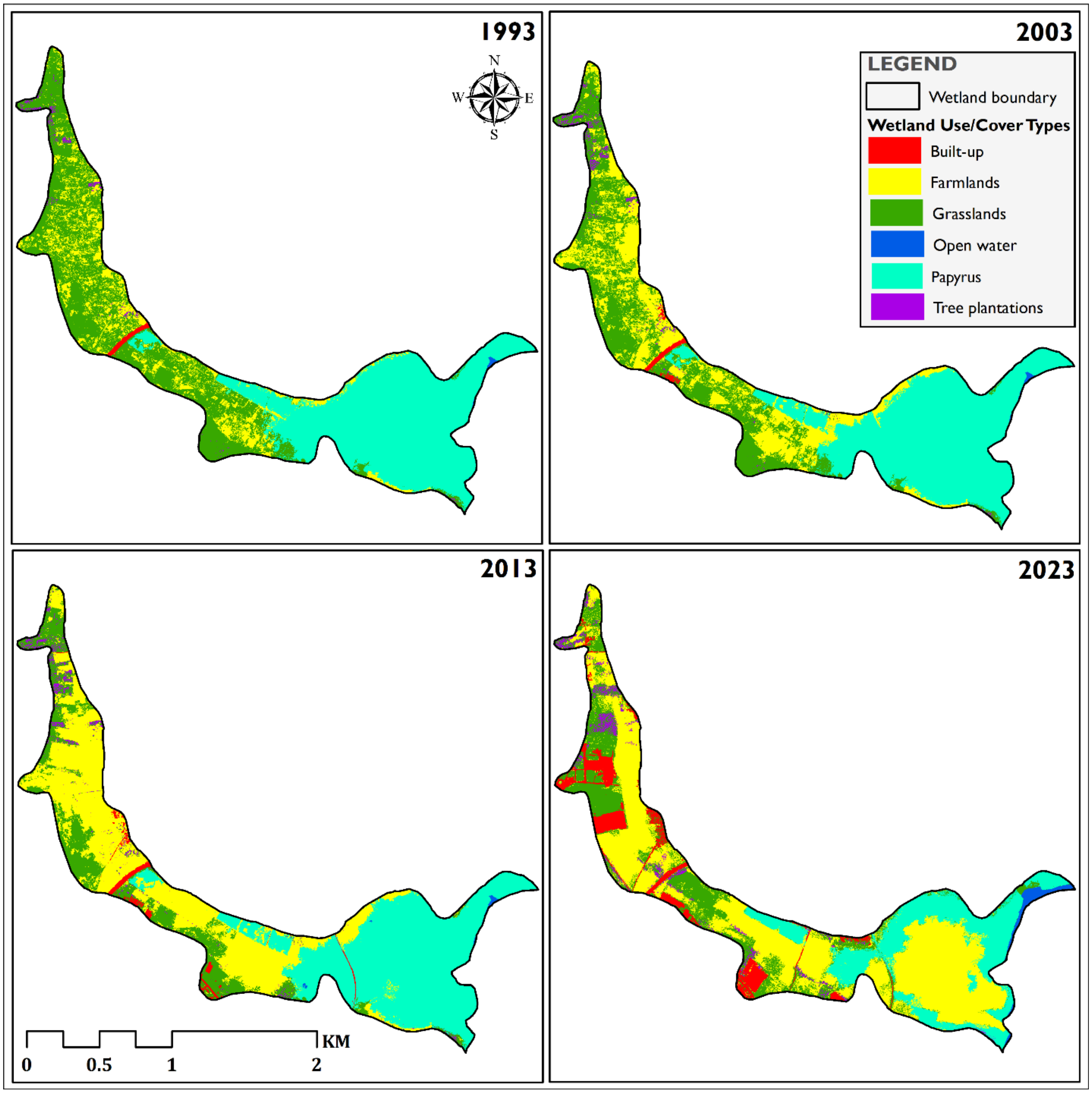

Figure 4. 2. Wetland use/cover types in Masese-Budhumbuli wetland in 1993, 2003, 2013, and 2023

The analysis of variance (ANOVA) showed that the changes in built-up areas, farmlands, grasslands, open water, papyrus, and tree plantations between 1993 and 2023 in Masese-Budhumbuli wetland were significant ($P<0.05$) (Table 4.2).

Table 4. 2. Analysis of variance in wetland use and cover changes in Masese-Budhumbuli wetland

Wetland Use and Cover Type	**Source of Variation**	**The sum of Square (s)**	**Df**	**Mean Square**	**F**	**Sig.**
Built-up	Between groups	0.034	3	0.011	25.085	0
	Within groups	8.35	18571	0		
	Total	8.383	18574			
Farmlands	Between groups	0.091	3	0.03	103.58	0
	Within groups	97.973	334276	0		
	Total	98.064	334279			
Grasslands	Between groups	0.181	3	0.06	32.288	0
	Within groups	278.38	149105	0.002		
	Total	278.57	149108			
Open water	Between groups	0.211	3	0.07	2856.2	0
	Within groups	0.338	13708	0		
	Total	0.549	13711			
Papyrus	Between groups	0.178	3	0.059	14.236	0
	Within groups	1131.1	271149	0.004		
	Total	1131.3	271152			
Tree plantations	Between groups	0.005	3	0.002	112.87	0
	Within groups	0.316	23721	0		
	Total	0.32	23724			

Between 1993 and 2023, most of the changes in Masese-Budhumbuli wetland were observed in the transition from papyrus to farmlands (22.8%), grasslands to farmlands (17.1%), grasslands to built-up areas (5.5%), farmlands to grasslands (4.1%), and papyrus to grasslands (2.8%) (Table 4.3 and Figure 4.3). The least transitions were seen from grasslands to open water, open water to papyrus, tree plantations to papyrus, and papyrus to tree plantations. No transitions were observed from built-up to open water, farmlands to open water, built-up to papyrus, open water to built-up, open water to farmlands, open water to grasslands, open water to tree plantations, and tree plantations to open water.

Table 4. 3. Transition matrix in wetland use and cover types between 1993 and 2023

YEAR		**2023**					
	Wetland Use/Cover Types	Built-up	Farmlands	Grasslands	Open water	Papyrus	Tree plantations
1993	Built-up	0.894	0.096	0.098	0	0	0.019
	Farmlands	3.686	16.136	8.782	0	1.364	1.003
	Grasslands	11.692	36.454	26.995	0.001	0.963	3.862
	Open water	0	0	0	0.531	0.004	0
	Papyrus	0.671	48.654	5.88	2.553	41.245	0.451
	Tree plantations	0.073	0.621	0.431	0	0.041	0.239

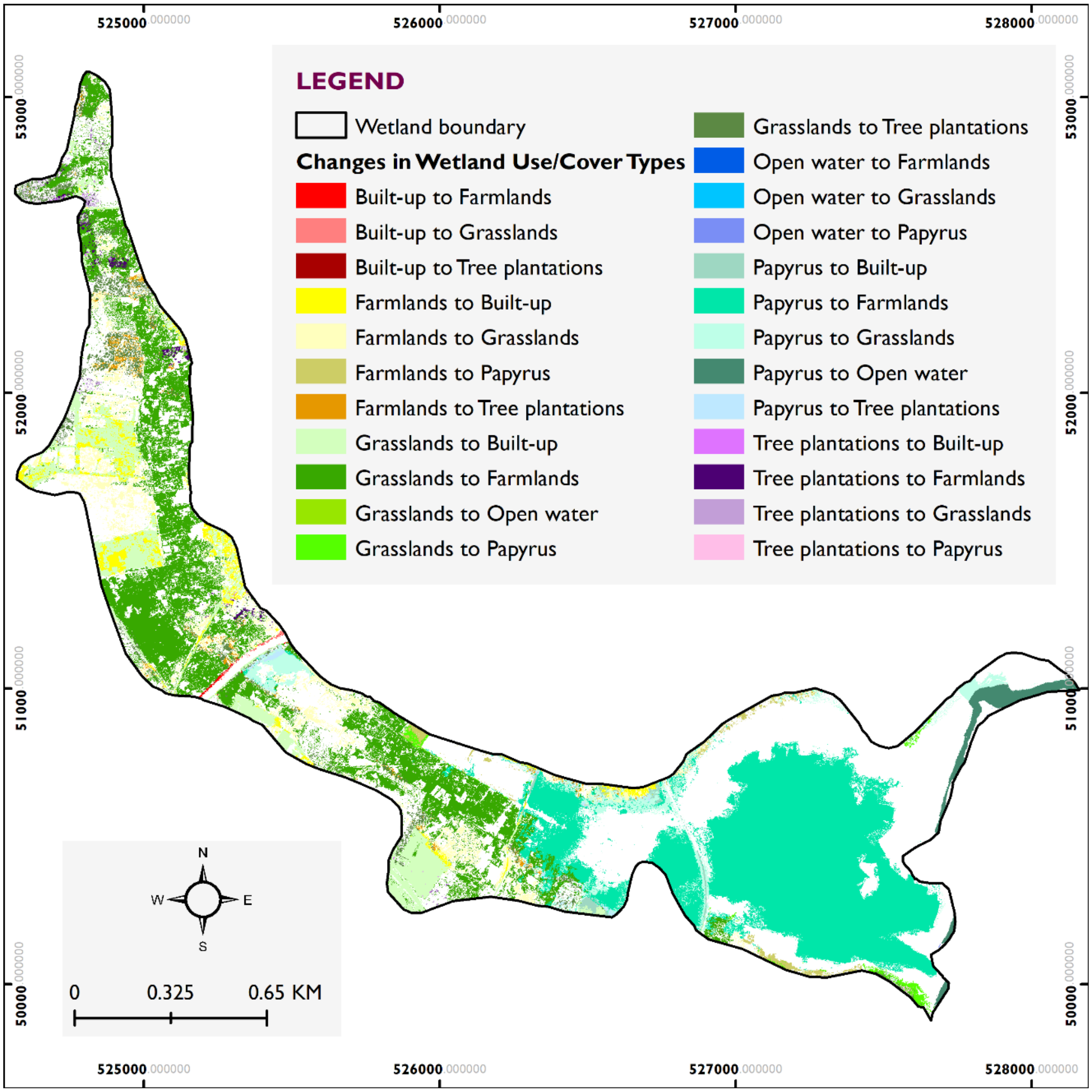

Figure 4. 3. Changes in wetland use/cover types in Masese-Budhumbuli wetland between 1993 and 2023

4.1.2 Sociodemographic characteristics of respondents

Most of the respondents around Masese-Budhumbuli wetland were mothers (39.5%), married (51.2%), females (50.9%), and their highest level of education was Ordinary level (30.2%) (Table 4.4). The respondents' major sources of livelihood included business trading (31.6%), fishing/fish farming (13.3%), crop farming (11.4%), casual laboring (10.6%), and transport services (8.2%) (Table 4.4). The average age of the respondents was 33.6 years and the average number of years lived around the wetland was 12.2 years.

Most respondents were engaged in business trading (31.6%), fishing/fish farming (13.3%), and crop farming (11.4%), activities that directly modify wetland habitats. Education levels and awareness of wetland benefits also shape resource-use decisions, with lower formal education potentially contributing to unsustainable practices. These social factors, together with population growth and settlement expansion, drive wetland transformations including the conversion of grasslands to built-up areas or papyrus to farmlands. Changes in wetland cover resulting from these human activities have measurable effects on plant species abundance, richness, and diversity in the wetland.

Table 4. 4. Sociodemographic characteristics of respondents in Masese-Budhumbuli wetland

Household position	**Frequency**	**Percent**
Father	143	37.9
Mother	149	39.5
Son	31	8.2
Daughter	29	7.7
Grandchild	6	1.6
Grandfather	6	1.6
Grandmother	13	3.4
Total	377	100

Marital status	**Frequency**	**Percent**
Cohabiting	51	13.5
Divorced	17	4.5
Married	193	51.2
Separated	24	6.4
Single	80	21.2
Widowed	12	3.2
Total	377	100

Education level	**Frequency**	**Percent**
No formal education	38	10.1
Primary	97	25.7
Ordinary (O) level	114	30.2
Advanced (A) level	39	10.3
Vocational training	60	15.9
Graduate (Diploma/Degree)	27	7.2
Postgraduate (Masters/PhD)	2	0.5
Total	377	100

Sources of livelihood	**Frequency**	**Percent**
Business trading	119	31.6
Carpenter	2	0.5
Casual laboring	40	10.6
Charity	3	0.8
Crop farming	43	11.4
Fishing/ fish farming	50	13.3
Formal employment	28	7.4
Livestock farming	22	5.8
None	11	2.9
Pension	1	0.3
Property income	9	2.4
Remittances from family and friends	15	4
Sand mining	2	0.5
Security guard	1	0.3
Transport services	31	8.2
Total	377	100

Sex	**Frequency**	**Percent**
Male	185	49.1
Female	192	50.9
Total	377	100

4.1.3 Drivers of wetland use and cover changes in Masese-Budhumbuli wetland

The Friedman test showed that the drivers of wetland use and cover changes in Masese-Budhumbuli wetland with high mean ranks include construction of industries, poverty, urbanization, population increase, construction of settlements, crop cultivation, weak enforcement of the wetlands policy, limited awareness about wetland benefits, and low cost of land in the wetland (Table 4.5). In fact, most of the respondents around the wetland strongly agreed that construction of industries (67.1%), urbanization (53.8%), poverty (53.1%), population increase (46.4%), construction of settlements (46.4%), and weak enforcement of the wetland policy (42.7%) are drivers of wetland use and cover changes (Table 4.5). There was statistically significant difference between the drivers of wetland use and cover changes in Masese-Budhumbuli wetland ($P<0.05$).

Table 4. 5. Friedman test of drivers of wetland use and cover changes

Drivers of wetland use/cover changes	**Strongly Agree N (%)**	**Agree N (%)**	**Neutral N (%)**	**Disagree N (%)**	**Strongly Disagree N (%)**	**Mean**	**SD**	**Mean Rank**
Construction of industries	253 (67.1)	101 (26.8)	10 (2.7)	9 (2.4)	4 (1.1)	4.56	0.76	14.56
Poverty	200 (53.1)	141 (37.4)	25 (6.6)	10 (2.7)	1 (0.3)	4.4	0.75	13.51
Urbanization	203 (53.8)	115 (30.5)	22 (5.8)	34 (9)	3 (0.8)	4.28	0.98	12.92
Population increases	175 (46.4)	156 (41.4)	22 (5.8)	22 (5.8)	2 (0.5)	4.27	0.86	12.81
Construction of settlements	175 (46.4)	155 (41.1)	18 (4.8)	26 (6.9)	3 (0.8)	4.25	0.89	12.71
Crop cultivation	156 (41.4)	151 (40.1)	53 (14.1)	14 (3.7)	3 (0.8)	4.18	0.86	12.11
Weak enforcement of the wetlands policy	161 (42.7)	125 (33.2)	32 (8.5)	50 (13.3)	9 (2.4)	4.01	1.12	11.47
Limited awareness about wetland benefits	135 (35.8)	135 (35.8)	55 (14.6)	46 (12.2)	6 (1.6)	3.92	1.06	10.76
Low cost of land in the wetland	136 (36.1)	130 (34.5)	57 (15.1)	50 (13.3)	4 (1.1)	3.91	1.07	10.71
Disposal of waste in the wetland	107 (28.4)	175 (46.4)	45 (11.9)	44 (11.7)	6 (1.6)	3.88	1	10.29
Political interference	120 (31.8)	144 (38.2)	44 (11.7)	61 (16.2)	8 (2.1)	3.81	1.11	10.22
People's perception of wetlands as free land	133 (35.3)	115 (30.5)	45 (11.9)	74 (19.6)	10 (2.7)	3.76	1.2	10.02

NB: N is the number of respondents and % is the percentage

Table 4. 5. Friedman test of drivers of wetland use and cover changes continued.

Drivers of wetland use/cover changes	**Strongly Agree N (%)**	**Agree N (%)**	**Neutral N (%)**	**Disagree N (%)**	**Strongly Disagree N (%)**	**Mean**	**SD**	**Mean Rank**
Dumping of murram sand in the wetland	103 (27.3)	144 (38.2)	47 (12.5)	71 (18.8)	12 (3.2)	3.68	1.16	9.64
Lack of coordination among stakeholders	65 (17.2)	214 (56.8)	61 (16.2)	33 (8.8)	4 (1.1)	3.8	0.86	9.58
Over harvesting of wetland resources	87 (23.1)	158 (41.9)	73 (19.4)	55 (14.6)	4 (1.1)	3.71	1.01	9.37
Grazing of livestock	80 (21.2)	157 (41.6)	49 (13)	63 (16.9)	28 (7.4)	3.53	1.21	8.75
Drought	83 (22)	117 (31)	110 (29.2)	63 (16.7)	4 (1.1)	3.56	1.04	8.59
Burning of wetland vegetation	57 (15.1)	165 (43.8)	63 (16.7)	83 (22)	9 (2.4)	3.47	1.07	7.98
Channeling of water into gardens	44 (11.7)	163 (43.2)	71 (18.8)	86 (22.8)	13 (3.4)	3.37	1.06	7.55
Introduction of invasive species	40 (10.6)	85 (22.5)	152 (40.3)	89 (23.6)	11 (2.9)	3.14	0.99	6.46

NB: N is the number of respondents and % is the percentage

4.1.4 Findings from Key Informant Interviews and Focus Group Discussions

The 12 key informant respondents reported that significant changes in the wetland occurred between 2005 and 2023, with the majority citing the period between 2010 and 2020 as the time of most significant change. The main drivers of wetland use and cover changes identified by the respondents include urbanization, industrialization, agricultural expansion, settlement, poverty, population increase, and weak regulation of wetland resources.

All respondents (100%) confirmed that there are plant species in Masese-Budhumbuli wetland that are resilient to disturbances, highlighting species like *Cyperus papyrus*, *Typha latifolia*, *Phragmites mauritianus*, *Ipomoea aquatica* among others. These findings suggest that despite the ongoing changes and disturbances in the wetland, some plant species are able to adapt and persist. The table 4.6 below presents the detailed findings from the key informant interviews.

Table 4. 6. Summary of key informant interview findings on wetland use, cover changes, and resilient plant species

Position	**No. of respondents**	**Year (s) of biggest change**	**Main drivers of wetland use and cover change**	**Resilient Plants (No/Yes)**	**Resilient plant species (scientific-local)**
District Natural Resources Officer	1	2015-2020	Urbanization, industrialization, agriculture, settlement, poverty	Yes	*Cyperus papyrus* (Bala), *Typha latifolia* (Mirembe), *Phragmites mauritianus* (Mululu)

Table 4. 6. Summary of key informant interview findings on wetland use, cover changes, and resilient plant species (Continued)

Position	**No. of respondents**	**Year (s) of biggest change**	**Main drivers of wetland use and cover change**	**Resilient Plants (No/Yes)**	**Resilient plant species (scientific-local)**
District Wetland Officer	1	2012-2018	Population increases, crop production like rice, waste accumulation, over harvest of papyrus	Yes	*Cyperus papyrus* (Bala), *Ipomoea aquatica* (Mukereere), *Ludwigia abyssinica* (Kibwabwa)
Village council (chairman, LC1 &committee)	4	2005-2015, 2018-2023	Settlement, farming, firewood, poor waste disposal, brick laying	Yes	*Rubia cordifolia* (Mukabala), *Hyptis capitata* (Muzura), *Polygonum senegalense* (Mbalagi)
Wetlands Management Department (MWE)	2	2010-2015, 2015-2020	Industrialization, effluent disposal, weak regulation, encroachment	Yes	*Cyperus papyrus* (Bala), *Eichhornia crassipes* (water hyacinth), *Panicum repens* (Kikuyu grass)

Table 4. 6. Summary of key informant interview findings on wetland use, cover changes, and resilient plant species (Continued)

Position/ Organization	**No. of respondents**	**Year (s) of biggest change**	**Main drivers of wetland use and cover change**	**Resilient Plants (No/Yes)**	**Resilient plant species (scientific-local)**
NEMA officer	1	2015-2020	Pollution, weak enforcement, population pressure	Yes	*Typha latifolia* (Mirembe), *Phragmites mauritianus* (Mululu), *Leersia hexandra*
IUCN representative	1	2008-2013	Agricultural intensification (rice growing), loss of traditional uses	Yes	*Cyperus papyrus* (Bala), *Ludwigia abyssinica* (Kibwabwa), *Commelina benhalensis*
Stakeholders from the wetlands management department	2	2012-2018, 2018-2023	Poverty driven extraction, car washing businesses, craft making from papyrus, waste, brick laying	Yes	*Ipomoea aquatica* (Mukereere), *Polygonum senegalense* (Mbalagi), *Cyperus rotundus*

Both the Focus Group Discussions identified the period 2000-2020 as the time of most noticeable change and mentioned divers such as small-scale rice growing, settlement, firewood collection, informal brick making, urbanization and waste dumping. Most of the participants agreed that certain wetland plants survive the disturbances, the species they listed varied slightly between two groups as shown in the table below.

Table 4. 7: Summary of Focus Group Discussions findings on wetland use, cover changes, and resilient plant species

No. of participants	**Year (s) of biggest change**	**Main drivers of wetland use and cover change**	**Resilient Plants (No/Yes)**	**Resilient plant species (scientific-local)**
6-12	2000-2028	Small sale rice farming, settlement, firewood collection, informal brick making	Yes	*Cyperus papyrus* (Bala), *Panicum repens* (Kikuyu grass), *Colocasia esculenta* (Mazi), *Commelina erecta*
6-12	2015-2020	Urbanization, population growth, waste dumping, charcoal production	Yes	*Cyperus papyrus* (Bala), *Cyperus esculentus* (Mukere), *Commelina diffusa* (Wakawaka), *Phragmites mauritianus* (Mululu)

4.3 Effect of wetland use and cover changes on plant species abundance and richness in Masese-Budhumbuli wetland, Jinja City

Generally, the changes in wetland use/cover types in Masese-Budhumbuli wetland did not have a significant impact on plant species abundance and richness ($P>0.05$) (Table 4.8). However, the post-hoc Tukey Honest Significance Difference (HSD) test showed that the changes from grasslands to built-up, grasslands to farmlands, grasslands to tree plantations, papyrus to farmlands, papyrus to grasslands, and farmlands to built-up; had a significant impact of plant species abundance and richness in Masese-Budhumbuli wetland ($P<0.05$) This indicates that while the overall variation across all wetland cover types was not significant, certain transitions between cover types are particularly influential in altering plant diversity (**Appendix 5**).

Table 4. 8. ANOVA table for effect of wetland use and cover changes on plant diversity

Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1744702.484	23	75856.630	1.430	.120
Within Groups	4667112.373	88	53035.368		
Total	**6411814.857**	**111**			

The plant species abundance data collected from the 112 plots in Masese-Budhumbuli wetland were not normally distributed, as indicated by the Kolmogorov-Smirnov test (K-S = 3.186, (P < 0.05) as shown in Table 4.9.

Table 4. 9. Kolmogorov-Smirnov normality test for the collected plant species data

		Abundance
N		112
Normal Parameters [a,b]	Mean	126.29
	Std. Deviation	240.342
Most Extreme Differences	Absolute	.301
	Positive	.257
	Negative	-.301
Kolmogorov-Smirnov Z		3.186
Asymp. Sig. (2-tailed)		0.000

NB: a. Test distribution is Normal. b. Calculated from the data.

The plant species richness in Masese-Budhumbuli wetland was 103 (85 herbs, 12 shrubs, and 6 trees). The plant species abundance is presented in **Appendix 5**. The most dominant plant species in the wetland were *Cyperus papyrus* (1,169), *Panicum repens* (582), *Colocasia esculenta* (450), *Commelina erecta* (386), *Cyperus esculenta* (313), and *Commelina diffusa* (265) as shown in Figure 4.4. The most dominant tree, shrub and herb plant species were

Eucalyptus camaldulensis (53.7%), *Eupatorium odoratum* (37.2%), and *Cyperus papyrus* (15.9%) respectively. The plant species in Masese-Budhumbuli wetland belonged to 48 families, however, the most common families were Poaceae (24.3%), Cyperaceae (9.7%), Asteraceae (4.9%), Commelinaceae (3.9%), and Onagraceae (3.9%) in Table 4.10.

Figure 4. 4. Plant species in Masese-Budhumbuli wetland. Plate 1: *Cyperus papyrus*, plate 2: *Panicum repens*, plate 3: *Colocasia esculenta*, plate 4: *Commelina erecta*, plate 5: *Cyperus esculenta*, and plate 6: *Commelina diffusa*

Table 4. 10. Families of plant species in Masese-Budhumbuli wetland

Growth form	**Family**	**Number of species**
Herb	Alismataceae	1
Herb	Amaranthaceae	2
Herb	Apiaceae	2
Herb	Araceae	1
Herb	Aspleniaceae	1
Herb	Asteraceae	5
Herb	Asteraceae	1
Herb	Athyriaceae	1
Herb	Ceratophyllaceae	1
Herb	Chlamydomonadaceae	1
Herb	Commelinaceae	4
Herb	Convolvulaceae	2
Herb	Cucurbitaceae	1
Herb	Cyperaceae	10
Herb	Dryopteridaceae	2
Herb	Euphorbiaceae	1
Herb	Fabaceae	3
Herb	Juncaceae	2
Herb	Lamiaceae	1
Herb	Lythraceae	1
Herb	Marsileaceae	2
Herb	Menispermaceae	1
Herb	Musaceae	1
Herb	Nelumbonaceae	1
Herb	Nymphaeaceae	3
Herb	Onagraceae	4
Herb	Oxalidaceae	1
Herb	Poaceae	25
Herb	Polygonaceae	1

Table 4.8: Families of plant species in Masese-Budhumbuli wetland (Continued)

Growth form	Family	Number of species
Herb	Pontederiaceae	1
Herb	Thelypteridaceae	1
Herb	Zygophyllaceae	1
Shrub	Asteraceae	1
Shrub	Convolvulaceae	1
Shrub	Cyperaceae	2
Shrub	Dioscoreaceae	1
Shrub	Euphorbiaceae	1
Shrub	Fabaceae	2
Shrub	Malvaceae	1
Shrub	Solanaceae	1
Shrub	Verbenaceae	1
Shrub	Vitaceae	1
Tree	Anacardiaceae	1
Tree	Arecaceae	1
Tree	Fabaceae	1
Tree	Lauraceae	1
Tree	Moraceae	1
Tree	Myrtaceae	1

Generally, the Shannon-Weiner Diversity Index for Masese-Budhumbuli wetland was 3.64, which means that the wetland has a very high plant species diversity, with many plant species that are equally abundant, suggesting great community stability and productivity. The Shannon-Weiner Evenness Index for Masese-Budhumbuli wetland was 0.77, which means that the plant species are equally distributed in the wetland.

Table 4.11 shows the Shannon-Weiner Diversity Index in the different wetland use and cover types of Masese-Budhumbuli wetland. Papyrus had the highest plant diversity followed by grasslands, and then tree plantations. The lowest plant diversity was noted in built-up areas, and open water.

Table 4. 11. Plant diversity in the different wetland use/cover types of Masese-Budhumbuli wetland in 2023

Wetland use/cover types	Shannon-Weiner Diversity Index
Papyrus	3.46
Grasslands	2.86
Farmlands	2.35
Tree plantations	2.42
Built-up	0.84
Open water	0.67

4.4 The ecological resilience of plants to wetland uses and cover changes in Masese-Budhumbuli wetland

The Pearson correlation analysis revealed a weak positive relationship between the ecological resilience of plants and changes in wetland use and cover in Masese-Budhumbuli wetland (Table 4.12). The relationship between the ecological resilience of plants and wetland uses and cover changes was statistically significant ($P<0.05$) (Table 4.12). This indicates that alterations in wetland cover such as conversion from grasslands, papyrus to built-up areas, farmlands have measurable effects on the ability of plant species to persist and recover, linking the dynamics of plant communities directly to patterns of wetland use and cover change.

Table 4. 12. Pearson correlation between wetland use and cover changes and ecological resilience

Factors		Wetland Use/Cover changes	Ecological Resilience
Wetland Uses and Cover	Pearson Correlation	1	.274**
	Sig. (2-tailed)		0
	Sum of Squares and Changes Cross-products	3549718.885	21131.918
	Covariance	27.193	0.162
	N	130541	130541 1
Ecological Resilience	Pearson Correlation	.274**	1
	Sig. (2-tailed)	0	
	Sum of Squares and Cross-products	21131.918	1677.677
	Covariance	0.162	0.013
	N	130541	130541

The ecological resilience of plants in Masese-Budhumbuli wetland was classified into very low, low, moderate, high, and very high (Table 4.13). The assessment showed that most plants within the wetland (37.1%) have a high ecological resilience to wetland use and cover changes. However, some wetland sections had plants with very low levels of ecological resilience.

Table 4. 13. Levels of ecological resilience in Masese-Budhumbuli wetland

Interval levels	Interval ranges	Level of ecological resilience	Area (Ha)	Percentage
A	0.182-0.388	Very Low	8.04	3.80
B	0.389-0.484	Low	17.81	8.42
C	0.484-0.573	Moderate	45.14	21.34
D	0.574-0.652	High	78.42	37.07
E	0.653-0.854	Very High	62.13	29.37

The upper and lower sections of the wetland had substantially higher levels of plant ecological resilience compared to middle parts of the wetland (Figure 4.5)**.**

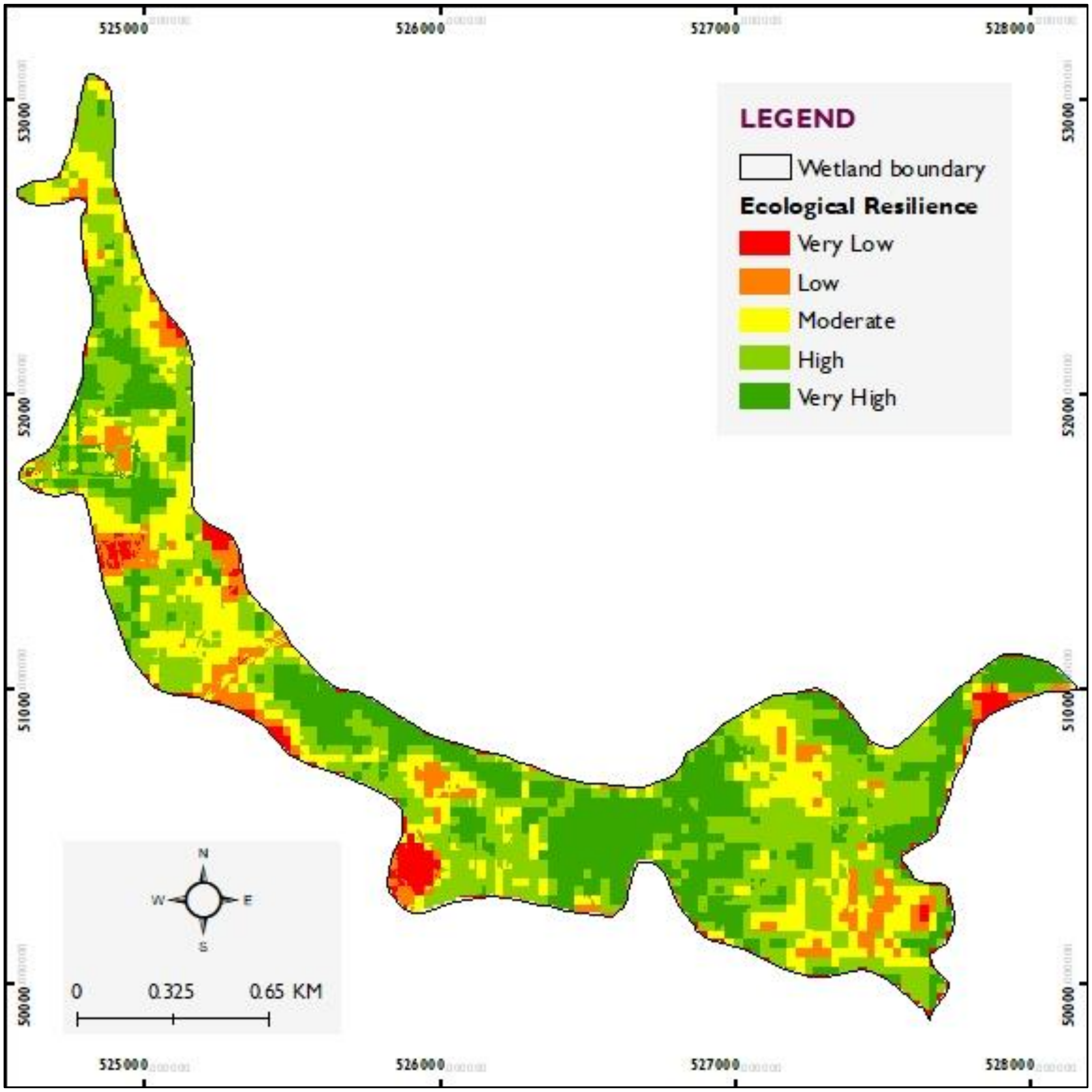

Figure 4. 5. Ecological resilience of plants in Masese-Budhumbuli wetland

The ecological resilience of built-up areas, open water, and tree plantations was low across the different classes of ecological resilience (Figure 4.6). Farmlands and grasslands exhibited a higher ecological resilience especially in the “moderate” and “high” classes of ecological resilience. The "very high" category of ecological resilience was dominated by papyrus (Figure 4.6).

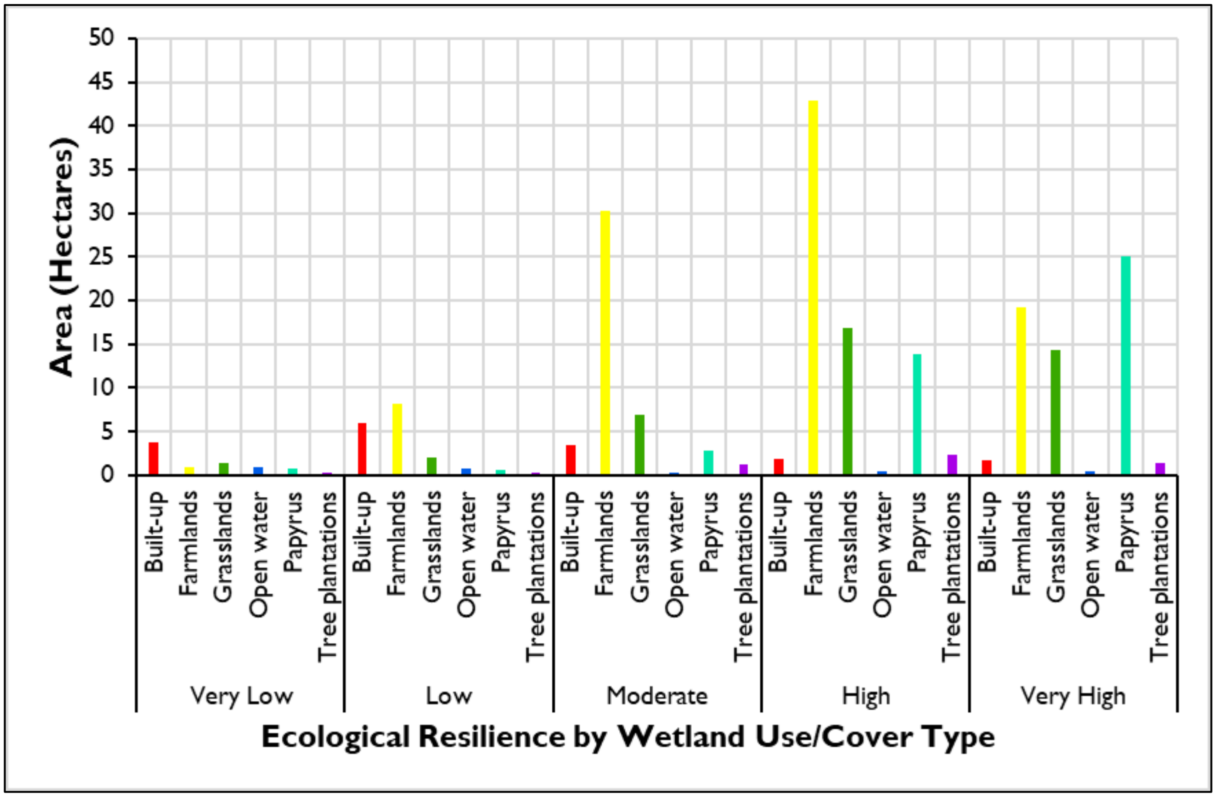

Figure 4. 6. Ecological resilience by wetland use/cover types of 2023 in Masese-Budhumbuli wetland

Most of the community members (62.3%) revealed that there are no plants in the Masese-Budhumbuli wetland that are resilient to wetland use and cover changes (Figure 4.7). However, a certain proportion of respondents (37.7%) believed that there are some plants within the wetland that are resilient to wetland use and cover changes. This implies that the community perception underscores the vulnerability of wetland plant communities and highlights the need for targeted conservation and management interventions to protect and enhance both plant diversity and ecosystem resilience

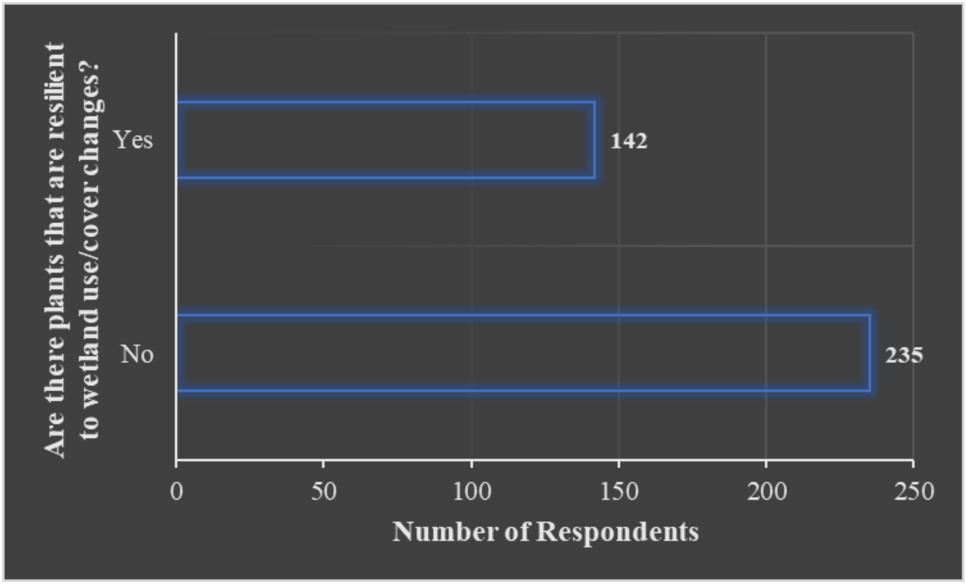

Figure 4. 7. Perceptions about the existence of plants in a wetland that are resilient to wetland use and cover changes

The local communities revealed that the plants that are mostly resilient to wetland uses and cover changes in Masese-Budhumbuli wetland include *Cyperus papyrus* (73.7%), *Rubia cordifolia* (6.6%), *Digitaria scalarum* (3.6%), *Eichhornia crassipes* (3.6%), and *Tradescantia zebrina* (3.6%) as shown in Table 4.14. The key informants also agree that these plants are highly resilient to wetland use and cover changes.

Table 4. 14. Perceptions of wetland plant species that are resilient to wetland use/cover changes in Masese-Budhumbuli wetland

Wetland plant species	**Number of respondents**	**Percentage**
Cyperus papyrus	101	73.7
Rubia cordifolia	9	6.6
Digitaria scalarum	5	3.6
Eichhornia crassipes	5	3.6
Tradescantia zebrina	5	3.6
Phragmites australis	3	2.2

Table 4. 14. Perceptions of wetland plant species that are resilient to wetland use/cover changes in Masese-Budhumbuli wetland (continued)

Wetland plant species	**Number of respondents**	**Percentage**
Pennisetum purpureum	2	1.5
Aframomum angustifolium	1	0.7
Agave sisalana	1	0.7
Cocos nucifera	1	0.7
Crassocephalum picridifolium	1	0.7
Eleusine indica	1	0.7
Hoslundia opposite	1	0.7
Momordica foetida	1	0.7
Total	**137**	**100**

CHAPTER FIVE: DISCUSSION

5.1 Introduction

This chapter interprets and discusses the study findings on wetland use, cover changes, plant diversity, and ecological resilience in Masese-Budhumbuli wetland, linking the results to existing literature and highlighting their ecological and socio-economic implications

5.2 Extent and drivers of wetland use and cover changes in Masese-Budhumbuli wetland, Jinja City

The increase in farmlands and built-up areas between 1993 and 2023 can be attributed to the population increase in Jinja City. Between 2014 and 2024, the population in Jinja City increased by 42,386 people (17%) (UBOS, 2024). This created demand for land for agriculture and settlement, thus leading to wetland encroachment. Gabiri *et al*. (2020) also observed an increased conversion of wetlands to built-up and agricultural areas between 1986 and 2016 around Kampala and Wakiso. Kayendeke *et al*., (2024) indicated that climate change, through altered rainfall patterns and increased droughts, contributes to wetland encroachment in Uganda as communities adapt by expanding agricultural activities into wetland areas.

The increase in farmlands can also be attributed to the wetlands' fertile soils and consistent water supply, which attract agricultural activities and lead to encroachment. Abuni *et al*. (2025) found that perennial cropping systems in Busega wetland exhibited higher nutrient concentrations, indicating soil fertility conducive to farming. The increase in built-up areas can also be attributed to the strategic placement of industries near wetlands, facilitating the direct discharge of untreated or partially treated effluents into these ecosystems (Angiro *et al*., 2020). Indeed, the communities reported the construction of industries as a major driver of wetland use and cover changes in the wetland.

Different social groups influence wetland use and cover change based on their livelihood needs and resource access. Farmers are key drivers of encroachment as declining and erratic rainfall forces them to shift cultivation into wetlands with fertile soils and reliable water (Kayendeke *et al*., 2024; Gabiri *et al*., 2020). While this supports short-term survival, it accelerates long-term wetland degradation. Industries contribute through land reclamation and effluent discharge, transforming vegetation cover and altering wetland soil and water quality (Angiro *et al*., 2020; Abuni *et al*., 2025). Women, who depend on wetlands for papyrus, water, and craft materials, also drive vegetation loss through resource overharvesting, though they can promote conservation when supported with alternative livelihoods (Turyahabwe *et al*., 2013; Matovu *et al*., 2024). Overall, climate variability and socio-economic pressures interact to intensify wetland conversion farming expands during droughts, industries occupy wetland fringes, and resource extraction increases, contributing to the decline of papyrus and grassland vegetation (Harun *et al*., 2021; Pietroiusti *et al*., 2024).

The increase in tree plantations can be attributed to the increased demand for fast-growing tree species like *Eucalyptus* and *Pine*, especially for timber, poles, and paper production (Kibet *et al*., 2021). Individuals and private companies establish tree plantations in wetlands due to the fertile soils and availability of water, which support rapid tree growth. Gabiri *et al*. (2020) observed that 12% of the encroached wetland areas between 1986 and 2016 in Kampala and Wakiso districts were converted into *Eucalyptus* tree plantations. The introduction of non-native tree species such as *Eucalyptus* can outcompete indigenous flora, leading to a decline in native plant and animal populations (Veldman *et al*., 2015). Xi *et al*. (2022) argued that large-scale tree planting programs intended for carbon sequestration have inadvertently led to the loss of protected wetlands. While tree planting is a valuable tool for climate mitigation, it is crucial to ensure that such initiatives are appropriately matched to the native ecosystems to prevent unintended ecological imbalances.

Across all respondent categories including district officials, wetland officers, community leaders, NEMA staff, and conservation agencies, the key drivers of wetland use and cover change were identified as urbanization, industrial development, settlement expansion, agricultural intensification (especially rice farming), population growth, poverty-driven resource extraction, weak regulation, and poor waste disposal practices. These qualitative insights reinforce the spatial and ecological evidence, showing that both formal development pressures and community livelihood strategies jointly contribute to the ongoing transformation of the wetland.

The reduction in papyrus and grasslands can be primarily attributed to conversions to wetland use types, such as farmlands, built-up areas, and tree plantations. Kuule *et al*. (2022), in their study on wetland vegetation and land-use changes in Uganda, found that agricultural and settlement expansion significantly reduced papyrus and grassland cover. Similarly, Matovu *et al*. (2024) observed that both agricultural encroachment and overharvesting of wetland resources by local communities contributed to vegetation decline.

The decline in papyrus can also be attributed to the overharvesting of the resources, especially for commercial purposes, without allowing for natural regeneration. Many respondents hinted at overharvesting of wetland resources as a driver of wetland use and cover changes. A study conducted in Lake Naivasha, Kenya, found that a six-month harvesting regime hurt aerial biomass production and young shoot regeneration compared to a twelve-month regime and unharvested controls (Terer *et al*., 2012). A reduction of papyrus vegetation has also been linked to invasive species such as water hyacinth (*Eichhornia crassipes*) that outcompete papyrus, limiting its growth in wetland ecosystems (Harun *et al*., 2021).

Open water was observed to have increased between 2013 and 2023. This can be attributed to increased water levels in Lake Victoria, particularly between 2019 and 2020. The lake water levels during this period rose by 1.21 meters, marking the highest increase in at least three decades (Pietroiusti *et al*., 2024). The increase in open water between 2013 and 2023 can also be attributed to drainage for agricultural expansion and diversion of water for irrigation. The satellite imagery showed an increase in farmlands in the lower section of the wetland. These activities reduce the extent of vegetated wetland areas and increase the area of open water. These findings confer with Turyahabwe *et al*., (2013) who observed an increase in open water of Kyoga plains wetlands, Uganda between 2000 and 2011.

5.3 Effect of wetland use and cover changes on plant species abundance and richness in Masese-Budhumbuli wetland, Jinja City

Although the wetland experienced notable changes in land use and cover, these alterations did not significantly affect plant species abundance and richness. This aligns with ecological evidence suggesting that plant communities in wetlands can remain relatively stable despite landscape-level disturbances, provided key ecological processes remain intact. Across respondent categories and field observations, it was noted that despite shifts in surrounding land uses, the core hydrological conditions of the wetland including periodic flooding, groundwater recharge, and seasonal water retention have remained relatively stable, supporting the persistence of dominant plant communities**.**

The wetland use and cover changes did not have a significant impact on plant species abundance and richness. Houlahan *et al*., (2006) argued that even when wetland cover changes, if hydrological conditions remain stable, plant diversity may not be significantly affected. The persistence of groundwater inflows, periodic flooding, or seasonal wet-dry cycles can maintain the ecological conditions necessary for wetland plant communities to thrive (Catford, 2017).

Wetlands often support a mix of specialist and generalist plant species that thrive in a variety of conditions, reducing the overall impact of habitat changes on diversity (Klaus & Noss, 2016). A study in the western Songnen Plain, China examined plant communities in wetlands subjected to various land-use practices, including natural conditions, mowing, light grazing combined with mowing, moderate grazing, and heavy grazing (Wang *et al*., 2022). The findings revealed that while the dominance of typical wetland plants like *Calamagrostis angustifolia* decreased under mowing or grazing, species diversity and richness were significantly higher in these managed wetlands compared to natural ones. This suggests that land-use changes can lead to generalist species' proliferation, thereby enhancing overall plant diversity.

Moreno-Mateos *et al*., (2012) also argued that if wetland use or cover changes are temporary or reversible, plant diversity may not be significantly affected in the long run, as wetlands can recover naturally when conditions are restored. Research in the Ghodaghodi Lake Complex, Nepal found that despite a decrease in forested lands from 2000 to 2022, there was an increase in plant species diversity (Naunyal *et al*., 2023). The study indicated that higher Normalized Difference Vegetation Index (NDVI) values corresponded to increased plant diversity, suggesting that changes in wetland cover did not adversely affect, and may have even enhanced, plant diversity in this context.

The wetland was dominated by plant species of the family Poaceae. This finding is consistent with Moges & Dibaba (2024), who found Asteraceae and Poaceae families as the most dominant families in Washa and Borale wetlands, in Ethiopia. The dominance of plant species of family Poaceae can be attributed to their adaptation to waterlogged soils, tolerance to periodic flooding, rapid growth and reproductive strategies, efficient nutrient uptake, tolerance to salinity and soil variability, resistance to disturbance, competitive exclusion of other plants, and seed dispersal adaptations (Landi *et al*., 2017; Muench & Elsey-Quirk, 2019; Yamauchi *et al*., 2020; Aslam *et al*., 2023).

Masese-Budhumbuli wetland was dominated by *Cyperus papyrus*. This dominance is consistent with findings in similar tropical wetlands across East Africa, such as the Lake Victoria basin, where papyrus is known to flourish in permanently inundated areas with low oxygen levels and high nutrient availability (Kansiime *et al*., 2007). The plant’s dominance is attributed to its clonal growth, high productivity, and competitive exclusion of other herbaceous wetland species, particularly under conditions of hydrological stability (Van Dam *et al*., 2014). In wetlands such as Nakivubo and Lutembe in Uganda, studies have similarly noted that papyrus not only provides habitat and breeding grounds for various species but also contributes significantly to nutrient retention and water purification (Kansiime & van Bruggen, 2001).

5.4 The ecological resilience of plants to wetland uses and cover changes in Masese-Budhumbuli wetland

A weak, positive, and significant correlation between wetland use and cover changes and ecological resilience of plants shows that other factors (such as seasonal flooding, managed grazing, and selective harvesting of vegetation) may also play a role in influencing plant resilience (Ponzio *et al*., 2019). A study examining the effects of seasonal flooding and livelihood activities found that vegetation in seasonally flooded zones, when subjected to harvesting, burning, or grazing, exhibited rapid regrowth, albeit shorter in stature (Hes *et al*., 2021). This suggests that such disturbances, in combination with flooding, can influence plant resilience and community structure.

Among all participants, including district officials, wetland officers, community leaders, NEMA staff, and conservation agencies, several plant species were consistently identified as resilient to disturbances associated with wetland use and cover change. These species—such as *Cyperus papyrus*, *Typha latifolia*, *Phragmites mauritianus*, *Ipomoea aquatica*, and others—were frequently cited for their ability to persist despite agricultural expansion, settlement growth, industrial waste disposal, and other human pressures. Their continued occurrence in the wetland supports the ecological evidence that Masese–Budhumbuli plant communities exhibit strong resilience under long-term anthropogenic disturbance.

The high ecological resilience of plants in Masese-Budhumbuli wetland (Figure 4.5) can be attributed to adaptive traits (such as seed dormancy and vegetative reproduction) that allow them to survive in fluctuating environmental conditions; species redundancy and functional diversity; hydrological buffering and ecological stability (Lavorel *et al*., 2015).

Wetlands host a rich diversity of plant species, ensuring that even if some species decline due to wetland cover changes, others with similar ecological functions can compensate (Brisson *et al*., 2020). Research conducted in the Upper Paraná River floodplain in Brazil assessed the relationship between plant diversity and community resilience following disturbances (Carvalho *et al*., 2012). The study found that plots with higher species richness exhibited greater resilience, suggesting that biodiversity enhances the stability and recovery potential of wetland plant communities.

Wetlands often have a persistent seed bank that allows plants to regenerate even after disturbances (Morimoto *et al*., 2017). For instance, a study in the Yellow River Delta wetlands highlighted that soil seed banks play a crucial role in vegetation establishment, succession, renewal, and biodiversity maintenance (Zhu *et al*., 2023). These seed banks can recruit species lost from aboveground vegetation, thereby promoting ecosystem resilience and aiding in wetland restoration efforts. Similarly, many wetland plants can regenerate through vegetative means, such as bud banks (Ott *et al*., 2019). The bud banks regulate the demography of dominant perennials, while seed banks contribute to the recruitment and dispersal of annual species (Chen *et al*., 2022). This complementary relationship ensures the persistence and resilience of macrophyte communities in wetland ecosystems.

Some community members identified *Cyperus papyrus* to be resilient to wetland use and cover changes. This finding agrees with Oyarmoi *et al*., (2024) who assessed hydrologic alterations in a papyrus-dominated wetland due to rice irrigation in Naigombwa catchment, Uganda. The research developed a conceptual ecological model linking the wetland's flow regime to biologically relevant hydrologic attributes, highlighting the resilience of papyrus wetlands to such changes. Geremew *et al*., (2018) attributed the high resilience of *Cyperus papyrus* to its fast growth rate, clonal reproduction, adaptability to water fluctuations, tolerance to pollution, and ability to recover after disturbances

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This chapter presents the key conclusions drawn from the study on Masese-Budhumbuli wetland, highlighting the main findings on wetland use, cover changes, plant diversity, and ecological resilience, and provides practical recommendations for sustainable wetland management and conservation.

6.2 Conclusion

This study examined the effect of wetland use and cover changes on plant diversity in Masese-Budhumbuli wetland. The findings revealed a significant increase in built-up areas, farmlands, and tree plantations, and a decline in grasslands and papyrus and Papyrus dominated 1993–2013, farmlands by 2023, and open water remained least. Between 1993-2023, built-up areas, farmlands, tree plantations, and open water increased, while papyrus and grasslands declined. Key transitions were observed in papyrus, farmlands, grasslands and farmlands. Changes were significant ($P < 0.05$) hence the null hypothesis stating that there are no significant changes in wetland use and cover of Masese-Budhumbuli wetland between 1993, 2003, 2013 and 2023 was rejected.

The main drivers of wetland use and cover changes in Masese-Budhumbuli which are the major factors influencing these changes include industrial construction, poverty, urbanization, population growth, settlement expansion, and weak policy enforcement with significant differences among them ($P < 0.05$).

Overall, wetland use and cover changes in Masese-Budhumbuli had no significant effect on plant abundance and richness ($P > 0.05$). Hence, the null hypothesis stating that the changes in wetland use and cover types do not significantly influence plant diversity in Masese-Budhumbuli wetland was accepted. Though specific transitions such as grasslands or papyrus to farmlands and built-up areas significantly affected diversity ($P < 0.05$). The wetland remains highly diverse and stable, dominated by resilient species like *Cyperus papyrus* and *Poaceae*, indicating that moderate disturbances have not substantially reduced its ecological functionality.

The correlation between wetland uses and cover changes and ecological resilience was weakly but significantly positively linked to wetland use and cover changes ($P < 0.05$). Hence the null hypothesis stating that there is no significant relationship between plant ecological resilience and wetland use and cover changes in the Masese-Budhumbuli wetland, Jinja City was rejected. Most species showed high resilience, especially papyrus, while built-up areas, open water, and tree plantations had low resilience. Community feedback highlighted vulnerability, with few species like *Cyperus papyrus* noted as highly resilient. These findings contribute to understanding wetland ecosystem dynamics and have important implications for conservation and sustainable management.

6.3 Recommendations

This study makes the following recommendations for each specific objective;

Objective I: To examine the extent and drivers of wetland use and cover changes in Masese-Budhumbuli wetland, Jinja City

- Local authorities and city planners should enforce land-use zoning to protect ecologically sensitive wetland areas, especially papyrus zones. Implementation includes zoning maps and buffer zones, led by NEMA, local governments, and the Ministry of Lands.

- Enforcement of Uganda's National Environment Act (2019) should be strengthened through regular compliance monitoring and penalties, overseen by NEMA and local environmental inspectors.
- Community-based wetland co-management programs should engage residents in conservation and sustainable practices. Local councils, NGOs, CBOs, and the Ministry of Water and Environment are responsible.
- Alternative livelihoods, such as sustainable aquaculture, agroforestry, and ecotourism, should be promoted to reduce dependence on wetland resources. Implementation involves training and support by local governments, NGOs, and extension services.
- Longitudinal research should track socio-economic and land-use changes influencing wetland encroachment, led by universities, research institutions, and NEMA.
- Land tenure and property rights in wetlands should be investigated to improve conservation and enforcement, with the Ministry of Lands, local authorities, and researchers responsible.

Objective II: To determine the effect of wetland use and cover changes on plant species abundance and richness

- To maintain the wetland's plant diversity which shown resilience to current land use and cover changes, there is need to promote sustainable land use practices to minimize future impacts, restoring degraded areas with native species and long term monitoring of plant diversity and ecosystem health.

- Long-term ecological monitoring using diversity indices, such as the Shannon-Weiner Index, should be institutionalized to track plant community changes. Implementation involves periodic surveys by NEMA, universities, and research institutions.
- Conservation efforts should focus on high-diversity areas, especially papyrus zones, to protect biodiversity and ecosystem services. Local governments, NGOs, and community groups are responsible for management and protection.
- Stakeholder awareness campaigns should highlight the ecological importance of plant diversity beyond species counts. Implementation includes workshops, outreach programs, and school initiatives, led by NGOs, local authorities, and community leaders.
- Future studies should assess seasonal and multi-year variability in plant communities to detect delayed impacts of wetland cover changes. Universities and research institutions should lead these studies.
- Investigations into wetland microhabitats and their relationship to species richness should be conducted to inform habitat-specific conservation strategies. This research can be undertaken by academic institutions, NEMA, and environmental NGOs.

Objective III: To determine the ecological resilience of plants to wetland use and cover changes

- Wetland restoration and rehabilitation should prioritize resilient species like Cyperus papyrus for their strong adaptive capacity. Local authorities, NGOs, and research institutions should lead planting programs.

- Regular monitoring of plant species identified as resilience indicators can assess ecosystem stability and recovery. This should be implemented by NEMA, universities, and community-based conservation groups.
- Ecological studies focusing on functional traits that confer resilience should guide adaptive wetland management and restoration frameworks. Academic institutions and environmental NGOs are responsible for these studies.
- Local ecological knowledge should be integrated into formal monitoring and decision-making, ensuring community input in conservation strategies. Community leaders, NGOs, and local authorities are key actors.
- In-depth research should explore the physiological and morphological traits that provide resilience in dominant and subdominant wetland species. Universities and research centers should lead this work.
- Additional studies should examine how plant resilience relates to ecosystem services, such as carbon sequestration and flood regulation, to improve both ecological and socio-economic valuation of wetlands. Research institutions and NEMA should coordinate these investigations.

6.4 Contributions of the study findings

The study provides several new insights into wetland dynamics in Masese-Budhumbuli, Jinja City, that build on and extend existing literature:

While previous studies (Gabiri *et al*., 2020; Kayendeke *et al*., 2024) have documented wetland encroachment broadly across Uganda, this study specifically quantifies land-use/cover changes in a rapidly urbanizing wetland in Jinja City over a 30-year period (1993-2023), providing fine-scale, spatially explicit analysis of trends.

Unlike many prior studies that emphasize biophysical or climate factors alone, this study combines community perceptions, socio-economic pressures, and ecological data to identify how different social groups farmers, industries, and women uniquely influence wetland use and cover changes.

While global studies suggest that wetland disturbances can increase plant diversity under certain conditions (Wang *et al*., 2022; Naunyal *et al*., 2023), this study demonstrates that overall plant species abundance and richness in Masese-Budhumbuli were not significantly affected by land-cover changes, highlighting the role of hydrological stability and community-specific resilience patterns.

The study uniquely categorizes wetland plant species based on their ecological resilience to land-use changes, identifying key resilient species such as Cyperus papyrus and linking resilience patterns to wetland management implications a perspective rarely addressed in prior Ugandan wetland studies.

By detailing specific transitions between wetland cover types (e.g., papyrus to farmlands, grasslands to built-up areas), the study provides actionable data on which land-cover changes are most influential in altering ecosystem structure, supporting targeted conservation and restoration interventions.

The study connects ecological findings with practical recommendations for urban planning, wetland zoning, and community-based management, bridging a gap between ecological research and policy implementation in the Ugandan context.

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APPENDICES

Appendix 1: Data collection sheet for plant species

Plot No: ………………………………………….

Latitude……………………………………………………………..

Longitude…………………………………………………………

Elevation ……………………………………………………….

NO.	Family	Species	DBH/DRC (cm)	Plot size

Appendix 2: Household Questionnaire

Dear respondent,

This questionnaire is for the purpose of helping Ms. Namatovu Faridah, a student of MSc. Conservation and Natural Resource Management at Kyambogo University to obtain information that will assist her to write a dissertation that is a partial requirement for this course. It is NOT meant for any other purpose; and therefore, information provided herein will be kept with utmost confidentiality. You are therefore kindly requested to cooperate in answering the questions honestly to provide the required information. The topic of study is "*Assessing the effect of wetland use and cover changes on plant diversity in Masese-Budhumbuli wetland, Jinja city, Eastern Uganda*". The interview will take about 30 minutes and your participation in this survey is completely voluntary.

LOCATION

Coordinates

Latitude……………………….Longitude……………………….Elevation…………………
……

SOCIO-ECONOMIC CHARACTERISTICS

Household Position

1. Father
2. Mother
3. Son
4. Daughter
5. Grandchild
6. Grandfather

7. Grandmother
8. Others

Sex of the respondent

1. Male
2. Female

How old are you (Age in complete years)?

…………………………………………….

What is your marital status?

1. Cohabiting
2. Divorced
3. Married
4. Separated
5. Single
6. Widowed

What is your highest level of education?

1. No formal education
2. Primary
3. Ordinary (O) level
4. Advanced (A) level
5. Specialized/Vocational training

6. Graduate (Diploma/Degree)
7. Post-graduate (Masters/PhD)
8. Others (Specify)…………

How many years have you lived in this village?

………………………………………………..

What is your major source of livelihood?

1. Crop farming
2. Livestock farming
3. Fishing/ fish farming
4. Formal employment
5. Causal laboring
6. Business/ trading
7. Transport services (Taxi operation/ *Boda-boda* riding)
8. Property income e.g. rentals
9. Pension
10. Remittances from family and friends
11. Charity
12. Others (Specify)………….

DRIVERS OF WETLAND USE AND COVER CHANGES AND PLANTS THAT ARE RESISTANT TO DISTURBANCES IN MASESE-BUDHUMBULI WETLAND

1.1 Rank the following driver(s) of wetland use and cover changes in Masese-Budhumbuli wetland.

Driver of wetland use and cover changes	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
Burning of wetland vegetation					
Channeling of water into gardens					
Construction of industries					
Construction of settlements					
Crop cultivation					
Disposal of waste in the wetland					
Drought					
Dumping of sand in the wetland					
Grazing of livestock					
Introduction of invasive/alien species					
Lack of coordination among stakeholders					
Limited awareness about the values of wetlands					
Low cost of land in the wetland					
Overharvesting of wetland resources					

Driver of wetland use and cover changes	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
People's perception of wetlands as free land					
Political interference					
Population increase					
Poverty					
Urbanization					
Weak enforcement of the wetlands policy					

1.2 Are there plants in the wetland that are resilient to disturbances such as farming?

a. Yes

b. No

1.3 If yes, list those plants that are resilient to disturbances

……………………………………………………………………………………………………

1.4 What should be done to conserve Masese-Budhumbuli wetland?

……………………………………………………………………………………………………

Appendix 3: Key Informant Guide

Dear respondent,

My name is Ms. Namatovu Faridah, a student of MSc. Conservation and Natural Resource Management at Kyambogo University. I am doing this survey to obtain information that will assist me to write a dissertation that is a partial requirement for this course. It is NOT meant for any other purpose; and therefore, information provided herein will be kept with utmost confidentiality. You are therefore kindly requested to cooperate in answering the questions honestly to provide the required information. My topic of study is "*Assessing the effect of wetland use and cover changes on plant diversity in Masese-Budhumbuli wetland, Jinja city, Eastern Uganda*". The interview will take about 20 minutes and your participation in this survey is completely voluntary.

Organization…………………………………………………………………….

Position of Respondent…………………………………………………………….

Questions

1. In which year(s) did the wetland change a lot?
2. What are the drivers of wetland use and cover changes in Masese-Budhumbuli wetland?
3. Are they some plants in Masese-Budhumbuli wetland that are resilient to disturbances?
4. If yes, mention those plants that are resilient to disturbances.

Appendix 4: Focus Group Discussion Guide

Hello everyone,

My name is Ms. Namatovu Faridah, a student of MSc. Conservation and Natural Resource Management at Kyambogo University. I am doing this survey to obtain information that will assist me to write a dissertation that is a partial requirement for this course. It is NOT meant for any other purpose; and therefore, information provided herein will be kept with utmost confidentiality. You are therefore kindly requested to cooperate in answering the questions honestly to provide the required information. My topic of study is "*Assessing the effect of wetland use and cover changes on plant diversity in Masese-Budhumbuli wetland, Jinja city, Eastern Uganda*".

Village……………………………………………………………….

Parish………………………………………………………………

Sub-county…………………………………………………………..

Questions

1. In which year(s) did the wetland change a lot?
2. What are the drivers of wetland use and cover changes in Masese-Budhumbuli wetland?
3. Are they some plants in Masese-Budhumbuli wetland that are resilient to disturbances?
4. If yes, mention those plants that are resilient to disturbances.

Appendix 5: Plant species abundance in Masese-Budhumbuli wetland

Growth habit	**Family**	**Plant species**	**Abundance**
Herb	Alismataceae	Sagittaria guayanensis	8
Herb	Amaranthaceae	Alternanthera philoxeriodes	7
Herb	Amaranthaceae	Alternanthera sessilis	65
Herb	Apiaceae	Hydrocotyle vulgaris	30
Herb	Apiaceae	Jussiaea repens	10

Growth habit	Family	Plant species	Abundance
Herb	Araceae	Colocasia esculenta	450
Herb	Aspleniaceae	Asplenium bulbiferum	7
Herb	Asteraceae	Arnica cordifolia	10
Herb	Asteraceae	Bidens pilosa	19
Herb	Asteraceae	Conzya sumatrensis	26
Herb	Asteraceae	Sonchus arvensis	90
Herb	Asteraceae	Synedrella nodiflora	20
Herb	Asteraceae	Ageratum conyzoides	126
Herb	Athyriaceae	Athyrium filix-femina	10
Herb	Ceratophyllaceae	Ceratophyllum demersum	4
Herb	Chlamydomonadaceae	Chlorophyta sensu stricto	20
Herb	Commelinaceae	Commelina communis	210
Herb	Commelinaceae	Commelina diffusa	265
Herb	Commelinaceae	Commelina erecta	386
Herb	Commelinaceae	Floscopa glomerata	4
Herb	Convolvulaceae	Ipomea aquatica	12
Herb	Convolvulaceae	Ipomea batatas	69
Herb	Cucurbitaceae	Cucurbita moschata	1
Herb	Cyperaceae	Cyperus articulatus	140
Herb	Cyperaceae	Cyperus digitatus	15
Herb	Cyperaceae	Cyperus esculenta	313
Herb	Cyperaceae	Cyperus malaccensis	10

Growth habit	Family	Plant species	Abundance
Herb	Cyperaceae	Cyperus papyrus	1169
Herb	Cyperaceae	Cyperus rotundus	57
Herb	Cyperaceae	Fimbristylis miliacea	5
Herb	Cyperaceae	Kyllinga pumila	74
Herb	Cyperaceae	Scirpus acutus	20
Herb	Cyperaceae	Scirpus maritimus	8
Herb	Dryopteridaceae	Dryopteris bissetiana	10
Herb	Dryopteridaceae	Dryopteris filix	8
Herb	Euphorbiaceae	Euphorbia hirta	87
Herb	Fabaceae	Aeschynomene fluitans	5
Herb	Fabaceae	Aeschynomene indica	2
Herb	Fabaceae	Strophostyles helvola	36
Herb	Juncaceae	Juncus effusus	242
Herb	Juncaceae	Juncus kraussii	20
Herb	Lamiaceae	Mentha Aquatica	2
Herb	Lythraceae	Ammannia coccinea	5
Herb	Marsileaceae	Marsilea minuta	24
Herb	Marsileaceae	Marsilea vestita	80
Herb	Menispermaceae	Stephania abyssinica	131
Herb	Musaceae	Musa Acuminata	6
Herb	Nelumbonaceae	Nelumbo nucifera	3
Herb	Nymphaeaceae	Nymphaea alba	2

Growth habit	Family	Plant species	Abundance
Herb	Nymphaeaceae	Nymphaea caerulea	3
Herb	Nymphaeaceae	Nymphoides indica	2
Herb	Onagraceae	Jussiaea repens	46
Herb	Onagraceae	Ludwigia hyssopifolia	23
Herb	Onagraceae	Ludwigia palustris	139
Herb	Onagraceae	Ludwigia peploides	77
Herb	Oxalidaceae	Oxalis corniculata	13
Herb	Poaceae	Chloris gayana	60
Herb	Poaceae	Coix Lacryma	6
Herb	Poaceae	Cynodon dactylon	16
Herb	Poaceae	Dinebra retroflexa	10
Herb	Poaceae	Echinochloa colona	180
Herb	Poaceae	Echinochloa crus-galli	200
Herb	Poaceae	Eragrostis ciliaris	95
Herb	Poaceae	Imperata cylindrica	171
Herb	Poaceae	Ipomoea batatas	4
Herb	Poaceae	Juncus effusus	90
Herb	Poaceae	Kyllinga pumila	4
Herb	Poaceae	Leersia oryzoides	59
Herb	Poaceae	Leersia Virginica	20
Herb	Poaceae	Panicum hemitomon	30
Herb	Poaceae	Panicum maximum	220

Growth habit	Family	Plant species	Abundance
Herb	Poaceae	Panicum repens	582
Herb	Poaceae	Pennisetum clandestinum	116
Herb	Poaceae	Pennisetum purpureum	10
Herb	Poaceae	Phalaris arundinacea	20
Herb	Poaceae	Saccharum officinarum	149
Herb	Poaceae	Spartina alterniflora	10
Herb	Poaceae	Spartina densiflora	10
Herb	Poaceae	Urochloa mutica	15
Herb	Poaceae	Zizania Aquatica	138
Herb	Poaceae	Zizania palustris	196
Herb	Polygonaceae	Persicaria barbata	10
Herb	Pontederiaceae	Eichhornia crassipes	130
Herb	Thelypteridaceae	Thelypteris palustris	163
Herb	Zygophyllaceae	Jarilla Heterophylla	9
Shrub	Asteraceae	Eupatorium odoratum	158
Shrub	Convolvulaceae	Ipomoea carnea	2
Shrub	Cyperaceae	Bolboschoenus fluviatilis	10
Shrub	Cyperaceae	Carex papyrus	6
Shrub	Dioscoreaceae	Dioscorea alata	12
Shrub	Euphorbiaceae	Manihot esculenta	16
Shrub	Fabaceae	Aeschynomene abyssinica	4
Shrub	Fabaceae	Mimosa pigra	37

Growth habit	Family	Plant species	Abundance
Shrub	Malvaceae	Hibiscus Sabdariffa	9
Shrub	Solanaceae	Solanum violaceum	3
Shrub	Verbenaceae	Lantana camara	15
Shrub	Vitaceae	Vitis trifolia	153
Tree	Anacardiaceae	Mangifera indica	2
Tree	Arecaceae	Elaeis guineensi	3
Tree	Fabaceae	Sesbania sesban	10
Tree	Lauraceae	Persea Americana	3
Tree	Moraceae	Artocarpus heterophyllus	1
Tree	Myrtaceae	Eucalyptus camaldulensis	22

Appendix 6: Post-hoc Tukey HSD test for effect of wetland use and cover changes on plant diversity

Multiple Comparisons

Dependent Variable: Abundance

Tukey HSD

(I) WUWC	(J) WUWC	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Built-up to farmlands	Built-up to grasslands	-210.000	230.294	1.000	-1074.82	654.82
	Built-up to tree plantations	-12.500	230.294	1.000	-877.32	852.32
	Farmlands to built-up	-765.833	210.229	.069	-1555.30	23.64
	Farmlands to grasslands	-214.667	188.034	1.000	-920.79	491.46
	Farmlands to papyrus	-47.500	230.294	1.000	-912.32	817.32
	Farmlands to tree plantations	-60.500	230.294	1.000	-925.32	804.32

	Grasslands to built-up	-103.600	178.385	1.000	-773.49	566.29
	Grasslands to farmlands	-108.222	171.651	1.000	-752.82	536.38
	Grasslands to open water	-7.000	230.294	1.000	-871.82	857.82
	Grasslands to papyrus	-98.000	230.294	1.000	-962.82	766.82
	Grasslands to tree plantations	-5.667	188.034	1.000	-711.79	700.46
	Open water to farmlands	-100.500	230.294	1.000	-965.32	764.32
	Open water to grasslands	-29.000	230.294	1.000	-893.82	835.82
	Open water to papyrus	-3.500	230.294	1.000	-868.32	861.32
	Papyrus to built-up	-87.500	230.294	1.000	-952.32	777.32
	Papyrus to farmlands	-150.380	169.231	1.000	-785.89	485.13
	Papyrus to grasslands	-162.056	180.029	1.000	-838.12	514.01
	Papyrus to open water	-13.000	230.294	1.000	-877.82	851.82
	Papyrus to tree plantations	1.500	230.294	1.000	-863.32	866.32
	Tree plantations to built-up	-76.500	230.294	1.000	-941.32	788.32
	Tree plantations to farmlands	5.000	230.294	1.000	-859.82	869.82
	Tree plantations to grasslands	1.000	230.294	1.000	-863.82	865.82
	Tree plantations to papyrus	-2.167	210.229	1.000	-791.64	787.30
Built-up to grasslands	Built-up to farmlands	210.000	230.294	1.000	-654.82	1074.82
	Built-up to tree plantations	197.500	230.294	1.000	-667.32	1062.32
	Farmlands to built-up	-555.833	210.229	.566	-1345.30	233.64
	Farmlands to grasslands	-4.667	188.034	1.000	-710.79	701.46
	Farmlands to papyrus	162.500	230.294	1.000	-702.32	1027.32
	Farmlands to tree plantations	149.500	230.294	1.000	-715.32	1014.32
	Grasslands to built-up	106.400	178.385	1.000	-563.49	776.29
	Grasslands to farmlands	101.778	171.651	1.000	-542.82	746.38
	Grasslands to open water	203.000	230.294	1.000	-661.82	1067.82
	Grasslands to papyrus	112.000	230.294	1.000	-752.82	976.82
	Grasslands to tree plantations	204.333	188.034	1.000	-501.79	910.46

	Open water to farmlands	109.500	230.294	1.000	-755.32	974.32
	Open water to grasslands	181.000	230.294	1.000	-683.82	1045.82
	Open water to papyrus	206.500	230.294	1.000	-658.32	1071.32
	Papyrus to built-up	122.500	230.294	1.000	-742.32	987.32
	Papyrus to farmlands	59.620	169.231	1.000	-575.89	695.13
	Papyrus to grasslands	47.944	180.029	1.000	-628.12	724.01
	Papyrus to open water	197.000	230.294	1.000	-667.82	1061.82
	Papyrus to tree plantations	211.500	230.294	1.000	-653.32	1076.32
	Tree plantations to built-up	133.500	230.294	1.000	-731.32	998.32
	Tree plantations to farmlands	215.000	230.294	1.000	-649.82	1079.82
	Tree plantations to grasslands	211.000	230.294	1.000	-653.82	1075.82
	Tree plantations to papyrus	207.833	210.229	1.000	-581.64	997.30
Built-up to tree plantations	Built-up to farmlands	12.500	230.294	1.000	-852.32	877.32
	Built-up to grasslands	-197.500	230.294	1.000	-1062.32	667.32
	Farmlands to built-up	-753.333	210.229	.081	-1542.80	36.14
	Farmlands to grasslands	-202.167	188.034	1.000	-908.29	503.96
	Farmlands to papyrus	-35.000	230.294	1.000	-899.82	829.82
	Farmlands to tree plantations	-48.000	230.294	1.000	-912.82	816.82
	Grasslands to built-up	-91.100	178.385	1.000	-760.99	578.79
	Grasslands to farmlands	-95.722	171.651	1.000	-740.32	548.88
	Grasslands to open water	5.500	230.294	1.000	-859.32	870.32
	Grasslands to papyrus	-85.500	230.294	1.000	-950.32	779.32
	Grasslands to tree plantations	6.833	188.034	1.000	-699.29	712.96
	Open water to farmlands	-88.000	230.294	1.000	-952.82	776.82
	Open water to grasslands	-16.500	230.294	1.000	-881.32	848.32
	Open water to papyrus	9.000	230.294	1.000	-855.82	873.82
	Papyrus to built-up	-75.000	230.294	1.000	-939.82	789.82
	Papyrus to farmlands	-137.880	169.231	1.000	-773.39	497.63
	Papyrus to grasslands	-149.556	180.029	1.000	-825.62	526.51
	Papyrus to open water	-.500	230.294	1.000	-865.32	864.32
	Papyrus to tree plantations	14.000	230.294	1.000	-850.82	878.82

	Tree plantations to built-up	-64.000	230.294	1.000	-928.82	800.82
	Tree plantations to farmlands	17.500	230.294	1.000	-847.32	882.32
	Tree plantations to grasslands	13.500	230.294	1.000	-851.32	878.32
	Tree plantations to papyrus	10.333	210.229	1.000	-779.14	799.80
	Built-up to farmlands	765.833	210.229	.069	-23.64	1555.30
	Built-up to grasslands	555.833	210.229	.566	-233.64	1345.30
	Built-up to tree plantations	753.333	210.229	.081	-36.14	1542.80
	Farmlands to grasslands	551.167	162.843	.136	-60.35	1162.69
	Farmlands to papyrus	718.333	210.229	.126	-71.14	1507.80
	Farmlands to tree plantations	705.333	210.229	.146	-84.14	1494.80
	Grasslands to built-up	662.233*	151.598	.007	92.94	1231.53
	Grasslands to farmlands	657.611*	143.614	.003	118.30	1196.92
	Grasslands to open water	758.833	210.229	.076	-30.64	1548.30
	Grasslands to papyrus	667.833	210.229	.221	-121.64	1457.30
	Grasslands to tree plantations	760.167*	162.843	.002	148.65	1371.69
Farmlands to built-up	Open water to farmlands	665.333	210.229	.227	-124.14	1454.80
	Open water to grasslands	736.833	210.229	.100	-52.64	1526.30
	Open water to papyrus	762.333	210.229	.072	-27.14	1551.80
	Papyrus to built-up	678.333	210.229	.198	-111.14	1467.80
	Papyrus to farmlands	615.453*	140.712	.007	87.04	1143.87
	Papyrus to grasslands	603.778*	153.529	.029	27.23	1180.32
	Papyrus to open water	752.833	210.229	.082	-36.64	1542.30
	Papyrus to tree plantations	767.333	210.229	.068	-22.14	1556.80
	Tree plantations to built-up	689.333	210.229	.175	-100.14	1478.80
	Tree plantations to farmlands	770.833	210.229	.064	-18.64	1560.30
	Tree plantations to grasslands	766.833	210.229	.068	-22.64	1556.30
	Tree plantations to papyrus	763.667*	188.034	.020	57.54	1469.79
Farmlands to grasslands	Built-up to farmlands	214.667	188.034	1.000	-491.46	920.79
	Built-up to grasslands	4.667	188.034	1.000	-701.46	710.79

	Built-up to tree plantations	202.167	188.034	1.000	-503.96	908.29
	Farmlands to built-up	-551.167	162.843	.136	-1162.69	60.35
	Farmlands to papyrus	167.167	188.034	1.000	-538.96	873.29
	Farmlands to tree plantations	154.167	188.034	1.000	-551.96	860.29
	Grasslands to built-up	111.067	118.923	1.000	-335.52	557.66
	Grasslands to farmlands	106.444	108.562	1.000	-301.24	514.12
	Grasslands to open water	207.667	188.034	1.000	-498.46	913.79
	Grasslands to papyrus	116.667	188.034	1.000	-589.46	822.79
	Grasslands to tree plantations	209.000	132.960	.996	-290.30	708.30
	Open water to farmlands	114.167	188.034	1.000	-591.96	820.29
	Open water to grasslands	185.667	188.034	1.000	-520.46	891.79
	Open water to papyrus	211.167	188.034	1.000	-494.96	917.29
	Papyrus to built-up	127.167	188.034	1.000	-578.96	833.29
	Papyrus to farmlands	64.287	104.693	1.000	-328.87	457.44
	Papyrus to grasslands	52.611	121.376	1.000	-403.19	508.41
	Papyrus to open water	201.667	188.034	1.000	-504.46	907.79
	Papyrus to tree plantations	216.167	188.034	1.000	-489.96	922.29
	Tree plantations to built-up	138.167	188.034	1.000	-567.96	844.29
	Tree plantations to farmlands	219.667	188.034	1.000	-486.46	925.79
	Tree plantations to grasslands	215.667	188.034	1.000	-490.46	921.79
	Tree plantations to papyrus	212.500	162.843	1.000	-399.02	824.02
Farmlands to papyrus	Built-up to farmlands	47.500	230.294	1.000	-817.32	912.32
	Built-up to grasslands	-162.500	230.294	1.000	-1027.32	702.32
	Built-up to tree plantations	35.000	230.294	1.000	-829.82	899.82
	Farmlands to built-up	-718.333	210.229	.126	-1507.80	71.14
	Farmlands to grasslands	-167.167	188.034	1.000	-873.29	538.96
	Farmlands to tree plantations	-13.000	230.294	1.000	-877.82	851.82
	Grasslands to built-up	-56.100	178.385	1.000	-725.99	613.79
	Grasslands to farmlands	-60.722	171.651	1.000	-705.32	583.88
	Grasslands to open water	40.500	230.294	1.000	-824.32	905.32

	Grasslands to papyrus	-50.500	230.294	1.000	-915.32	814.32
	Grasslands to tree plantations	41.833	188.034	1.000	-664.29	747.96
	Open water to farmlands	-53.000	230.294	1.000	-917.82	811.82
	Open water to grasslands	18.500	230.294	1.000	-846.32	883.32
	Open water to papyrus	44.000	230.294	1.000	-820.82	908.82
	Papyrus to built-up	-40.000	230.294	1.000	-904.82	824.82
	Papyrus to farmlands	-102.880	169.231	1.000	-738.39	532.63
	Papyrus to grasslands	-114.556	180.029	1.000	-790.62	561.51
	Papyrus to open water	34.500	230.294	1.000	-830.32	899.32
	Papyrus to tree plantations	49.000	230.294	1.000	-815.82	913.82
	Tree plantations to built-up	-29.000	230.294	1.000	-893.82	835.82
	Tree plantations to farmlands	52.500	230.294	1.000	-812.32	917.32
	Tree plantations to grasslands	48.500	230.294	1.000	-816.32	913.32
	Tree plantations to papyrus	45.333	210.229	1.000	-744.14	834.80
Farmlands to tree plantations	Built-up to farmlands	60.500	230.294	1.000	-804.32	925.32
	Built-up to grasslands	-149.500	230.294	1.000	-1014.32	715.32
	Built-up to tree plantations	48.000	230.294	1.000	-816.82	912.82
	Farmlands to built-up	-705.333	210.229	.146	-1494.80	84.14
	Farmlands to grasslands	-154.167	188.034	1.000	-860.29	551.96
	Farmlands to papyrus	13.000	230.294	1.000	-851.82	877.82
	Grasslands to built-up	-43.100	178.385	1.000	-712.99	626.79
	Grasslands to farmlands	-47.722	171.651	1.000	-692.32	596.88
	Grasslands to open water	53.500	230.294	1.000	-811.32	918.32
	Grasslands to papyrus	-37.500	230.294	1.000	-902.32	827.32
	Grasslands to tree plantations	54.833	188.034	1.000	-651.29	760.96
	Open water to farmlands	-40.000	230.294	1.000	-904.82	824.82
	Open water to grasslands	31.500	230.294	1.000	-833.32	896.32
	Open water to papyrus	57.000	230.294	1.000	-807.82	921.82
	Papyrus to built-up	-27.000	230.294	1.000	-891.82	837.82
	Papyrus to farmlands	-89.880	169.231	1.000	-725.39	545.63
	Papyrus to grasslands	-101.556	180.029	1.000	-777.62	574.51

	Papyrus to open water	47.500	230.294	1.000	-817.32	912.32
	Papyrus to tree plantations	62.000	230.294	1.000	-802.82	926.82
	Tree plantations to built-up	-16.000	230.294	1.000	-880.82	848.82
	Tree plantations to farmlands	65.500	230.294	1.000	-799.32	930.32
	Tree plantations to grasslands	61.500	230.294	1.000	-803.32	926.32
	Tree plantations to papyrus	58.333	210.229	1.000	-731.14	847.80
	Built-up to farmlands	103.600	178.385	1.000	-566.29	773.49
	Built-up to grasslands	-106.400	178.385	1.000	-776.29	563.49
	Built-up to tree plantations	91.100	178.385	1.000	-578.79	760.99
	Farmlands to built-up	-662.233*	151.598	.007	-1231.53	-92.94
	Farmlands to grasslands	-111.067	118.923	1.000	-557.66	335.52
	Farmlands to papyrus	56.100	178.385	1.000	-613.79	725.99
	Farmlands to tree plantations	43.100	178.385	1.000	-626.79	712.99
	Grasslands to farmlands	-4.622	90.829	1.000	-345.71	336.47
	Grasslands to open water	96.600	178.385	1.000	-573.29	766.49
	Grasslands to papyrus	5.600	178.385	1.000	-664.29	675.49
	Grasslands to tree plantations	97.933	118.923	1.000	-348.66	544.52
Grasslands to built-up	Open water to farmlands	3.100	178.385	1.000	-666.79	672.99
	Open water to grasslands	74.600	178.385	1.000	-595.29	744.49
	Open water to papyrus	100.100	178.385	1.000	-569.79	769.99
	Papyrus to built-up	16.100	178.385	1.000	-653.79	685.99
	Papyrus to farmlands	-46.780	86.168	1.000	-370.37	276.81
	Papyrus to grasslands	-58.456	105.813	1.000	-455.81	338.90
	Papyrus to open water	90.600	178.385	1.000	-579.29	760.49
	Papyrus to tree plantations	105.100	178.385	1.000	-564.79	774.99
	Tree plantations to built-up	27.100	178.385	1.000	-642.79	696.99
	Tree plantations to farmlands	108.600	178.385	1.000	-561.29	778.49
	Tree plantations to grasslands	104.600	178.385	1.000	-565.29	774.49
	Tree plantations to papyrus	101.433	151.598	1.000	-467.86	670.73

	Built-up to farmlands	108.222	171.651	1.000	-536.38	752.82
	Built-up to grasslands	-101.778	171.651	1.000	-746.38	542.82
	Built-up to tree plantations	95.722	171.651	1.000	-548.88	740.32
	Farmlands to built-up	-657.611*	143.614	.003	-1196.92	-118.30
	Farmlands to grasslands	-106.444	108.562	1.000	-514.12	301.24
	Farmlands to papyrus	60.722	171.651	1.000	-583.88	705.32
	Farmlands to tree plantations	47.722	171.651	1.000	-596.88	692.32
	Grasslands to built-up	4.622	90.829	1.000	-336.47	345.71
	Grasslands to open water	101.222	171.651	1.000	-543.38	745.82
	Grasslands to papyrus	10.222	171.651	1.000	-634.38	654.82
	Grasslands to tree plantations	102.556	108.562	1.000	-305.12	510.24
Grasslands to farmlands	Open water to farmlands	7.722	171.651	1.000	-636.88	652.32
	Open water to grasslands	79.222	171.651	1.000	-565.38	723.82
	Open water to papyrus	104.722	171.651	1.000	-539.88	749.32
	Papyrus to built-up	20.722	171.651	1.000	-623.88	665.32
	Papyrus to farmlands	-42.158	71.189	1.000	-309.49	225.18
	Papyrus to grasslands	-53.833	94.017	1.000	-406.89	299.23
	Papyrus to open water	95.222	171.651	1.000	-549.38	739.82
	Papyrus to tree plantations	109.722	171.651	1.000	-534.88	754.32
	Tree plantations to built-up	31.722	171.651	1.000	-612.88	676.32
	Tree plantations to farmlands	113.222	171.651	1.000	-531.38	757.82
	Tree plantations to grasslands	109.222	171.651	1.000	-535.38	753.82
	Tree plantations to papyrus	106.056	143.614	1.000	-433.25	645.37
	Built-up to farmlands	7.000	230.294	1.000	-857.82	871.82
	Built-up to grasslands	-203.000	230.294	1.000	-1067.82	661.82
	Built-up to tree plantations	-5.500	230.294	1.000	-870.32	859.32
Grasslands to open water	Farmlands to built-up	-758.833	210.229	.076	-1548.30	30.64
	Farmlands to grasslands	-207.667	188.034	1.000	-913.79	498.46
	Farmlands to papyrus	-40.500	230.294	1.000	-905.32	824.32
	Farmlands to tree plantations	-53.500	230.294	1.000	-918.32	811.32

	Grasslands to built-up	-96.600	178.385	1.000	-766.49	573.29
	Grasslands to farmlands	-101.222	171.651	1.000	-745.82	543.38
	Grasslands to papyrus	-91.000	230.294	1.000	-955.82	773.82
	Grasslands to tree plantations	1.333	188.034	1.000	-704.79	707.46
	Open water to farmlands	-93.500	230.294	1.000	-958.32	771.32
	Open water to grasslands	-22.000	230.294	1.000	-886.82	842.82
	Open water to papyrus	3.500	230.294	1.000	-861.32	868.32
	Papyrus to built-up	-80.500	230.294	1.000	-945.32	784.32
	Papyrus to farmlands	-143.380	169.231	1.000	-778.89	492.13
	Papyrus to grasslands	-155.056	180.029	1.000	-831.12	521.01
	Papyrus to open water	-6.000	230.294	1.000	-870.82	858.82
	Papyrus to tree plantations	8.500	230.294	1.000	-856.32	873.32
	Tree plantations to built-up	-69.500	230.294	1.000	-934.32	795.32
	Tree plantations to farmlands	12.000	230.294	1.000	-852.82	876.82
	Tree plantations to grasslands	8.000	230.294	1.000	-856.82	872.82
	Tree plantations to papyrus	4.833	210.229	1.000	-784.64	794.30
Grasslands to papyrus	Built-up to farmlands	98.000	230.294	1.000	-766.82	962.82
	Built-up to grasslands	-112.000	230.294	1.000	-976.82	752.82
	Built-up to tree plantations	85.500	230.294	1.000	-779.32	950.32
	Farmlands to built-up	-667.833	210.229	.221	-1457.30	121.64
	Farmlands to grasslands	-116.667	188.034	1.000	-822.79	589.46
	Farmlands to papyrus	50.500	230.294	1.000	-814.32	915.32
	Farmlands to tree plantations	37.500	230.294	1.000	-827.32	902.32
	Grasslands to built-up	-5.600	178.385	1.000	-675.49	664.29
	Grasslands to farmlands	-10.222	171.651	1.000	-654.82	634.38
	Grasslands to open water	91.000	230.294	1.000	-773.82	955.82
	Grasslands to tree plantations	92.333	188.034	1.000	-613.79	798.46
	Open water to farmlands	-2.500	230.294	1.000	-867.32	862.32
	Open water to grasslands	69.000	230.294	1.000	-795.82	933.82
	Open water to papyrus	94.500	230.294	1.000	-770.32	959.32

	Papyrus to built-up	10.500	230.294	1.000	-854.32	875.32
	Papyrus to farmlands	-52.380	169.231	1.000	-687.89	583.13
	Papyrus to grasslands	-64.056	180.029	1.000	-740.12	612.01
	Papyrus to open water	85.000	230.294	1.000	-779.82	949.82
	Papyrus to tree plantations	99.500	230.294	1.000	-765.32	964.32
	Tree plantations to built-up	21.500	230.294	1.000	-843.32	886.32
	Tree plantations to farmlands	103.000	230.294	1.000	-761.82	967.82
	Tree plantations to grasslands	99.000	230.294	1.000	-765.82	963.82
	Tree plantations to papyrus	95.833	210.229	1.000	-693.64	885.30
Grasslands to tree plantations	Built-up to farmlands	5.667	188.034	1.000	-700.46	711.79
	Built-up to grasslands	-204.333	188.034	1.000	-910.46	501.79
	Built-up to tree plantations	-6.833	188.034	1.000	-712.96	699.29
	Farmlands to built-up	-760.167*	162.843	.002	-1371.69	-148.65
	Farmlands to grasslands	-209.000	132.960	.996	-708.30	290.30
	Farmlands to papyrus	-41.833	188.034	1.000	-747.96	664.29
	Farmlands to tree plantations	-54.833	188.034	1.000	-760.96	651.29
	Grasslands to built-up	-97.933	118.923	1.000	-544.52	348.66
	Grasslands to farmlands	-102.556	108.562	1.000	-510.24	305.12
	Grasslands to open water	-1.333	188.034	1.000	-707.46	704.79
	Grasslands to papyrus	-92.333	188.034	1.000	-798.46	613.79
	Open water to farmlands	-94.833	188.034	1.000	-800.96	611.29
	Open water to grasslands	-23.333	188.034	1.000	-729.46	682.79
	Open water to papyrus	2.167	188.034	1.000	-703.96	708.29
	Papyrus to built-up	-81.833	188.034	1.000	-787.96	624.29
	Papyrus to farmlands	-144.713	104.693	.999	-537.87	248.44
	Papyrus to grasslands	-156.389	121.376	1.000	-612.19	299.41
	Papyrus to open water	-7.333	188.034	1.000	-713.46	698.79
	Papyrus to tree plantations	7.167	188.034	1.000	-698.96	713.29
	Tree plantations to built-up	-70.833	188.034	1.000	-776.96	635.29
	Tree plantations to farmlands	10.667	188.034	1.000	-695.46	716.79

	Tree plantations to grasslands	6.667	188.034	1.000	-699.46	712.79
	Tree plantations to papyrus	3.500	162.843	1.000	-608.02	615.02
Open water to farmlands	Built-up to farmlands	100.500	230.294	1.000	-764.32	965.32
	Built-up to grasslands	-109.500	230.294	1.000	-974.32	755.32
	Built-up to tree plantations	88.000	230.294	1.000	-776.82	952.82
	Farmlands to built-up	-665.333	210.229	.227	-1454.80	124.14
	Farmlands to grasslands	-114.167	188.034	1.000	-820.29	591.96
	Farmlands to papyrus	53.000	230.294	1.000	-811.82	917.82
	Farmlands to tree plantations	40.000	230.294	1.000	-824.82	904.82
	Grasslands to built-up	-3.100	178.385	1.000	-672.99	666.79
	Grasslands to farmlands	-7.722	171.651	1.000	-652.32	636.88
	Grasslands to open water	93.500	230.294	1.000	-771.32	958.32
	Grasslands to papyrus	2.500	230.294	1.000	-862.32	867.32
	Grasslands to tree plantations	94.833	188.034	1.000	-611.29	800.96
	Open water to grasslands	71.500	230.294	1.000	-793.32	936.32
	Open water to papyrus	97.000	230.294	1.000	-767.82	961.82
	Papyrus to built-up	13.000	230.294	1.000	-851.82	877.82
	Papyrus to farmlands	-49.880	169.231	1.000	-685.39	585.63
	Papyrus to grasslands	-61.556	180.029	1.000	-737.62	614.51
	Papyrus to open water	87.500	230.294	1.000	-777.32	952.32
	Papyrus to tree plantations	102.000	230.294	1.000	-762.82	966.82
	Tree plantations to built-up	24.000	230.294	1.000	-840.82	888.82
	Tree plantations to farmlands	105.500	230.294	1.000	-759.32	970.32
	Tree plantations to grasslands	101.500	230.294	1.000	-763.32	966.32
	Tree plantations to papyrus	98.333	210.229	1.000	-691.14	887.80
Open water to grasslands	Built-up to farmlands	29.000	230.294	1.000	-835.82	893.82
	Built-up to grasslands	-181.000	230.294	1.000	-1045.82	683.82
	Built-up to tree plantations	16.500	230.294	1.000	-848.32	881.32
	Farmlands to built-up	-736.833	210.229	.100	-1526.30	52.64
	Farmlands to grasslands	-185.667	188.034	1.000	-891.79	520.46

	Farmlands to papyrus	-18.500	230.294	1.000	-883.32	846.32
	Farmlands to tree plantations	-31.500	230.294	1.000	-896.32	833.32
	Grasslands to built-up	-74.600	178.385	1.000	-744.49	595.29
	Grasslands to farmlands	-79.222	171.651	1.000	-723.82	565.38
	Grasslands to open water	22.000	230.294	1.000	-842.82	886.82
	Grasslands to papyrus	-69.000	230.294	1.000	-933.82	795.82
	Grasslands to tree plantations	23.333	188.034	1.000	-682.79	729.46
	Open water to farmlands	-71.500	230.294	1.000	-936.32	793.32
	Open water to papyrus	25.500	230.294	1.000	-839.32	890.32
	Papyrus to built-up	-58.500	230.294	1.000	-923.32	806.32
	Papyrus to farmlands	-121.380	169.231	1.000	-756.89	514.13
	Papyrus to grasslands	-133.056	180.029	1.000	-809.12	543.01
	Papyrus to open water	16.000	230.294	1.000	-848.82	880.82
	Papyrus to tree plantations	30.500	230.294	1.000	-834.32	895.32
	Tree plantations to built-up	-47.500	230.294	1.000	-912.32	817.32
	Tree plantations to farmlands	34.000	230.294	1.000	-830.82	898.82
	Tree plantations to grasslands	30.000	230.294	1.000	-834.82	894.82
	Tree plantations to papyrus	26.833	210.229	1.000	-762.64	816.30
Open water to papyrus	Built-up to farmlands	3.500	230.294	1.000	-861.32	868.32
	Built-up to grasslands	-206.500	230.294	1.000	-1071.32	658.32
	Built-up to tree plantations	-9.000	230.294	1.000	-873.82	855.82
	Farmlands to built-up	-762.333	210.229	.072	-1551.80	27.14
	Farmlands to grasslands	-211.167	188.034	1.000	-917.29	494.96
	Farmlands to papyrus	-44.000	230.294	1.000	-908.82	820.82
	Farmlands to tree plantations	-57.000	230.294	1.000	-921.82	807.82
	Grasslands to built-up	-100.100	178.385	1.000	-769.99	569.79
	Grasslands to farmlands	-104.722	171.651	1.000	-749.32	539.88
	Grasslands to open water	-3.500	230.294	1.000	-868.32	861.32
	Grasslands to papyrus	-94.500	230.294	1.000	-959.32	770.32

	Grasslands to tree plantations	-2.167	188.034	1.000	-708.29	703.96
	Open water to farmlands	-97.000	230.294	1.000	-961.82	767.82
	Open water to grasslands	-25.500	230.294	1.000	-890.32	839.32
	Papyrus to built-up	-84.000	230.294	1.000	-948.82	780.82
	Papyrus to farmlands	-146.880	169.231	1.000	-782.39	488.63
	Papyrus to grasslands	-158.556	180.029	1.000	-834.62	517.51
	Papyrus to open water	-9.500	230.294	1.000	-874.32	855.32
	Papyrus to tree plantations	5.000	230.294	1.000	-859.82	869.82
	Tree plantations to built-up	-73.000	230.294	1.000	-937.82	791.82
	Tree plantations to farmlands	8.500	230.294	1.000	-856.32	873.32
	Tree plantations to grasslands	4.500	230.294	1.000	-860.32	869.32
	Tree plantations to papyrus	1.333	210.229	1.000	-788.14	790.80
Papyrus to built-up	Built-up to farmlands	87.500	230.294	1.000	-777.32	952.32
	Built-up to grasslands	-122.500	230.294	1.000	-987.32	742.32
	Built-up to tree plantations	75.000	230.294	1.000	-789.82	939.82
	Farmlands to built-up	-678.333	210.229	.198	-1467.80	111.14
	Farmlands to grasslands	-127.167	188.034	1.000	-833.29	578.96
	Farmlands to papyrus	40.000	230.294	1.000	-824.82	904.82
	Farmlands to tree plantations	27.000	230.294	1.000	-837.82	891.82
	Grasslands to built-up	-16.100	178.385	1.000	-685.99	653.79
	Grasslands to farmlands	-20.722	171.651	1.000	-665.32	623.88
	Grasslands to open water	80.500	230.294	1.000	-784.32	945.32
	Grasslands to papyrus	-10.500	230.294	1.000	-875.32	854.32
	Grasslands to tree plantations	81.833	188.034	1.000	-624.29	787.96
	Open water to farmlands	-13.000	230.294	1.000	-877.82	851.82
	Open water to grasslands	58.500	230.294	1.000	-806.32	923.32
	Open water to papyrus	84.000	230.294	1.000	-780.82	948.82
	Papyrus to farmlands	-62.880	169.231	1.000	-698.39	572.63
	Papyrus to grasslands	-74.556	180.029	1.000	-750.62	601.51
	Papyrus to open water	74.500	230.294	1.000	-790.32	939.32

	Papyrus to tree plantations	89.000	230.294	1.000	-775.82	953.82
	Tree plantations to built-up	11.000	230.294	1.000	-853.82	875.82
	Tree plantations to farmlands	92.500	230.294	1.000	-772.32	957.32
	Tree plantations to grasslands	88.500	230.294	1.000	-776.32	953.32
	Tree plantations to papyrus	85.333	210.229	1.000	-704.14	874.80
Papyrus to farmlands	Built-up to farmlands	150.380	169.231	1.000	-485.13	785.89
	Built-up to grasslands	-59.620	169.231	1.000	-695.13	575.89
	Built-up to tree plantations	137.880	169.231	1.000	-497.63	773.39
	Farmlands to built-up	-615.453*	140.712	.007	-1143.87	-87.04
	Farmlands to grasslands	-64.287	104.693	1.000	-457.44	328.87
	Farmlands to papyrus	102.880	169.231	1.000	-532.63	738.39
	Farmlands to tree plantations	89.880	169.231	1.000	-545.63	725.39
	Grasslands to built-up	46.780	86.168	1.000	-276.81	370.37
	Grasslands to farmlands	42.158	71.189	1.000	-225.18	309.49
	Grasslands to open water	143.380	169.231	1.000	-492.13	778.89
	Grasslands to papyrus	52.380	169.231	1.000	-583.13	687.89
	Grasslands to tree plantations	144.713	104.693	.999	-248.44	537.87
	Open water to farmlands	49.880	169.231	1.000	-585.63	685.39
	Open water to grasslands	121.380	169.231	1.000	-514.13	756.89
	Open water to papyrus	146.880	169.231	1.000	-488.63	782.39
	Papyrus to built-up	62.880	169.231	1.000	-572.63	698.39
	Papyrus to grasslands	-11.676	89.522	1.000	-347.86	324.51
	Papyrus to open water	137.380	169.231	1.000	-498.13	772.89
	Papyrus to tree plantations	151.880	169.231	1.000	-483.63	787.39
	Tree plantations to built-up	73.880	169.231	1.000	-561.63	709.39
	Tree plantations to farmlands	155.380	169.231	1.000	-480.13	790.89
	Tree plantations to grasslands	151.380	169.231	1.000	-484.13	786.89
	Tree plantations to papyrus	148.213	140.712	1.000	-380.20	676.63
Papyrus to grasslands	Built-up to farmlands	162.056	180.029	1.000	-514.01	838.12

	Built-up to grasslands	-47.944	180.029	1.000	-724.01	628.12
	Built-up to tree plantations	149.556	180.029	1.000	-526.51	825.62
	Farmlands to built-up	-603.778*	153.529	.029	-1180.32	-27.23
	Farmlands to grasslands	-52.611	121.376	1.000	-508.41	403.19
	Farmlands to papyrus	114.556	180.029	1.000	-561.51	790.62
	Farmlands to tree plantations	101.556	180.029	1.000	-574.51	777.62
	Grasslands to built-up	58.456	105.813	1.000	-338.90	455.81
	Grasslands to farmlands	53.833	94.017	1.000	-299.23	406.89
	Grasslands to open water	155.056	180.029	1.000	-521.01	831.12
	Grasslands to papyrus	64.056	180.029	1.000	-612.01	740.12
	Grasslands to tree plantations	156.389	121.376	1.000	-299.41	612.19
	Open water to farmlands	61.556	180.029	1.000	-614.51	737.62
	Open water to grasslands	133.056	180.029	1.000	-543.01	809.12
	Open water to papyrus	158.556	180.029	1.000	-517.51	834.62
	Papyrus to built-up	74.556	180.029	1.000	-601.51	750.62
	Papyrus to farmlands	11.676	89.522	1.000	-324.51	347.86
	Papyrus to open water	149.056	180.029	1.000	-527.01	825.12
	Papyrus to tree plantations	163.556	180.029	1.000	-512.51	839.62
	Tree plantations to built-up	85.556	180.029	1.000	-590.51	761.62
	Tree plantations to farmlands	167.056	180.029	1.000	-509.01	843.12
	Tree plantations to grasslands	163.056	180.029	1.000	-513.01	839.12
	Tree plantations to papyrus	159.889	153.529	1.000	-416.66	736.44
	Built-up to farmlands	13.000	230.294	1.000	-851.82	877.82
	Built-up to grasslands	-197.000	230.294	1.000	-1061.82	667.82
	Built-up to tree plantations	.500	230.294	1.000	-864.32	865.32
	Farmlands to built-up	-752.833	210.229	.082	-1542.30	36.64
Papyrus to open water	Farmlands to grasslands	-201.667	188.034	1.000	-907.79	504.46
	Farmlands to papyrus	-34.500	230.294	1.000	-899.32	830.32
	Farmlands to tree plantations	-47.500	230.294	1.000	-912.32	817.32
	Grasslands to built-up	-90.600	178.385	1.000	-760.49	579.29

	Grasslands to farmlands	-95.222	171.651	1.000	-739.82	549.38
	Grasslands to open water	6.000	230.294	1.000	-858.82	870.82
	Grasslands to papyrus	-85.000	230.294	1.000	-949.82	779.82
	Grasslands to tree plantations	7.333	188.034	1.000	-698.79	713.46
	Open water to farmlands	-87.500	230.294	1.000	-952.32	777.32
	Open water to grasslands	-16.000	230.294	1.000	-880.82	848.82
	Open water to papyrus	9.500	230.294	1.000	-855.32	874.32
	Papyrus to built-up	-74.500	230.294	1.000	-939.32	790.32
	Papyrus to farmlands	-137.380	169.231	1.000	-772.89	498.13
	Papyrus to grasslands	-149.056	180.029	1.000	-825.12	527.01
	Papyrus to tree plantations	14.500	230.294	1.000	-850.32	879.32
	Tree plantations to built-up	-63.500	230.294	1.000	-928.32	801.32
	Tree plantations to farmlands	18.000	230.294	1.000	-846.82	882.82
	Tree plantations to grasslands	14.000	230.294	1.000	-850.82	878.82
	Tree plantations to papyrus	10.833	210.229	1.000	-778.64	800.30
	Built-up to farmlands	-1.500	230.294	1.000	-866.32	863.32
	Built-up to grasslands	-211.500	230.294	1.000	-1076.32	653.32
	Built-up to tree plantations	-14.000	230.294	1.000	-878.82	850.82
	Farmlands to built-up	-767.333	210.229	.068	-1556.80	22.14
	Farmlands to grasslands	-216.167	188.034	1.000	-922.29	489.96
	Farmlands to papyrus	-49.000	230.294	1.000	-913.82	815.82
	Farmlands to tree plantations	-62.000	230.294	1.000	-926.82	802.82
Papyrus to tree plantations	Grasslands to built-up	-105.100	178.385	1.000	-774.99	564.79
	Grasslands to farmlands	-109.722	171.651	1.000	-754.32	534.88
	Grasslands to open water	-8.500	230.294	1.000	-873.32	856.32
	Grasslands to papyrus	-99.500	230.294	1.000	-964.32	765.32
	Grasslands to tree plantations	-7.167	188.034	1.000	-713.29	698.96
	Open water to farmlands	-102.000	230.294	1.000	-966.82	762.82
	Open water to grasslands	-30.500	230.294	1.000	-895.32	834.32
	Open water to papyrus	-5.000	230.294	1.000	-869.82	859.82

	Papyrus to built-up	-89.000	230.294	1.000	-953.82	775.82
	Papyrus to farmlands	-151.880	169.231	1.000	-787.39	483.63
	Papyrus to grasslands	-163.556	180.029	1.000	-839.62	512.51
	Papyrus to open water	-14.500	230.294	1.000	-879.32	850.32
	Tree plantations to built-up	-78.000	230.294	1.000	-942.82	786.82
	Tree plantations to farmlands	3.500	230.294	1.000	-861.32	868.32
	Tree plantations to grasslands	-.500	230.294	1.000	-865.32	864.32
	Tree plantations to papyrus	-3.667	210.229	1.000	-793.14	785.80
Tree plantations to built-up	Built-up to farmlands	76.500	230.294	1.000	-788.32	941.32
	Built-up to grasslands	-133.500	230.294	1.000	-998.32	731.32
	Built-up to tree plantations	64.000	230.294	1.000	-800.82	928.82
	Farmlands to built-up	-689.333	210.229	.175	-1478.80	100.14
	Farmlands to grasslands	-138.167	188.034	1.000	-844.29	567.96
	Farmlands to papyrus	29.000	230.294	1.000	-835.82	893.82
	Farmlands to tree plantations	16.000	230.294	1.000	-848.82	880.82
	Grasslands to built-up	-27.100	178.385	1.000	-696.99	642.79
	Grasslands to farmlands	-31.722	171.651	1.000	-676.32	612.88
	Grasslands to open water	69.500	230.294	1.000	-795.32	934.32
	Grasslands to papyrus	-21.500	230.294	1.000	-886.32	843.32
	Grasslands to tree plantations	70.833	188.034	1.000	-635.29	776.96
	Open water to farmlands	-24.000	230.294	1.000	-888.82	840.82
	Open water to grasslands	47.500	230.294	1.000	-817.32	912.32
	Open water to papyrus	73.000	230.294	1.000	-791.82	937.82
	Papyrus to built-up	-11.000	230.294	1.000	-875.82	853.82
	Papyrus to farmlands	-73.880	169.231	1.000	-709.39	561.63
	Papyrus to grasslands	-85.556	180.029	1.000	-761.62	590.51
	Papyrus to open water	63.500	230.294	1.000	-801.32	928.32
	Papyrus to tree plantations	78.000	230.294	1.000	-786.82	942.82
	Tree plantations to farmlands	81.500	230.294	1.000	-783.32	946.32

	Tree plantations to grasslands	77.500	230.294	1.000	-787.32	942.32
	Tree plantations to papyrus	74.333	210.229	1.000	-715.14	863.80
	Built-up to farmlands	-5.000	230.294	1.000	-869.82	859.82
	Built-up to grasslands	-215.000	230.294	1.000	-1079.82	649.82
	Built-up to tree plantations	-17.500	230.294	1.000	-882.32	847.32
	Farmlands to built-up	-770.833	210.229	.064	-1560.30	18.64
	Farmlands to grasslands	-219.667	188.034	1.000	-925.79	486.46
	Farmlands to papyrus	-52.500	230.294	1.000	-917.32	812.32
	Farmlands to tree plantations	-65.500	230.294	1.000	-930.32	799.32
	Grasslands to built-up	-108.600	178.385	1.000	-778.49	561.29
	Grasslands to farmlands	-113.222	171.651	1.000	-757.82	531.38
	Grasslands to open water	-12.000	230.294	1.000	-876.82	852.82
	Grasslands to papyrus	-103.000	230.294	1.000	-967.82	761.82
Tree plantations to farmlands	Grasslands to tree plantations	-10.667	188.034	1.000	-716.79	695.46
	Open water to farmlands	-105.500	230.294	1.000	-970.32	759.32
	Open water to grasslands	-34.000	230.294	1.000	-898.82	830.82
	Open water to papyrus	-8.500	230.294	1.000	-873.32	856.32
	Papyrus to built-up	-92.500	230.294	1.000	-957.32	772.32
	Papyrus to farmlands	-155.380	169.231	1.000	-790.89	480.13
	Papyrus to grasslands	-167.056	180.029	1.000	-843.12	509.01
	Papyrus to open water	-18.000	230.294	1.000	-882.82	846.82
	Papyrus to tree plantations	-3.500	230.294	1.000	-868.32	861.32
	Tree plantations to built-up	-81.500	230.294	1.000	-946.32	783.32
	Tree plantations to grasslands	-4.000	230.294	1.000	-868.82	860.82
	Tree plantations to papyrus	-7.167	210.229	1.000	-796.64	782.30
	Built-up to farmlands	-1.000	230.294	1.000	-865.82	863.82
	Built-up to grasslands	-211.000	230.294	1.000	-1075.82	653.82
Tree plantations to grasslands	Built-up to tree plantations	-13.500	230.294	1.000	-878.32	851.32
	Farmlands to built-up	-766.833	210.229	.068	-1556.30	22.64
	Farmlands to grasslands	-215.667	188.034	1.000	-921.79	490.46
	Farmlands to papyrus	-48.500	230.294	1.000	-913.32	816.32

	Farmlands to tree plantations	-61.500	230.294	1.000	-926.32	803.32
	Grasslands to built-up	-104.600	178.385	1.000	-774.49	565.29
	Grasslands to farmlands	-109.222	171.651	1.000	-753.82	535.38
	Grasslands to open water	-8.000	230.294	1.000	-872.82	856.82
	Grasslands to papyrus	-99.000	230.294	1.000	-963.82	765.82
	Grasslands to tree plantations	-6.667	188.034	1.000	-712.79	699.46
	Open water to farmlands	-101.500	230.294	1.000	-966.32	763.32
	Open water to grasslands	-30.000	230.294	1.000	-894.82	834.82
	Open water to papyrus	-4.500	230.294	1.000	-869.32	860.32
	Papyrus to built-up	-88.500	230.294	1.000	-953.32	776.32
	Papyrus to farmlands	-151.380	169.231	1.000	-786.89	484.13
	Papyrus to grasslands	-163.056	180.029	1.000	-839.12	513.01
	Papyrus to open water	-14.000	230.294	1.000	-878.82	850.82
	Papyrus to tree plantations	.500	230.294	1.000	-864.32	865.32
	Tree plantations to built-up	-77.500	230.294	1.000	-942.32	787.32
	Tree plantations to farmlands	4.000	230.294	1.000	-860.82	868.82
	Tree plantations to papyrus	-3.167	210.229	1.000	-792.64	786.30
Tree plantations to papyrus	Built-up to farmlands	2.167	210.229	1.000	-787.30	791.64
	Built-up to grasslands	-207.833	210.229	1.000	-997.30	581.64
	Built-up to tree plantations	-10.333	210.229	1.000	-799.80	779.14
	Farmlands to built-up	-763.667*	188.034	.020	-1469.79	-57.54
	Farmlands to grasslands	-212.500	162.843	1.000	-824.02	399.02
	Farmlands to papyrus	-45.333	210.229	1.000	-834.80	744.14
	Farmlands to tree plantations	-58.333	210.229	1.000	-847.80	731.14
	Grasslands to built-up	-101.433	151.598	1.000	-670.73	467.86
	Grasslands to farmlands	-106.056	143.614	1.000	-645.37	433.25
	Grasslands to open water	-4.833	210.229	1.000	-794.30	784.64
	Grasslands to papyrus	-95.833	210.229	1.000	-885.30	693.64

	Grasslands to tree plantations	-3.500	162.843	1.000	-615.02	608.02
	Open water to farmlands	-98.333	210.229	1.000	-887.80	691.14
	Open water to grasslands	-26.833	210.229	1.000	-816.30	762.64
	Open water to papyrus	-1.333	210.229	1.000	-790.80	788.14
	Papyrus to built-up	-85.333	210.229	1.000	-874.80	704.14
	Papyrus to farmlands	-148.213	140.712	1.000	-676.63	380.20
	Papyrus to grasslands	-159.889	153.529	1.000	-736.44	416.66
	Papyrus to open water	-10.833	210.229	1.000	-800.30	778.64
	Papyrus to tree plantations	3.667	210.229	1.000	-785.80	793.14
	Tree plantations to built-up	-74.333	210.229	1.000	-863.80	715.14
	Tree plantations to farmlands	7.167	210.229	1.000	-782.30	796.64
	Tree plantations to grasslands	3.167	210.229	1.000	-786.30	792.64

*. The mean difference is significant at the 0.05 level.