

**ECOLOGICAL AND ECONOMIC BENEFITS OF INTEGRATING FISH INTO  
RICE FARMING AT MWEA IRRIGATION SCHEME IN KIRINYAGA  
COUNTY, KENYA**

**MERCY MUTHONI WAMBUGU (BSc.)**

**N50/CE/28769/2014**

**A Thesis Submitted in partial fulfillment for award of the Degree of Master of  
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University**

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## **DECLARATION AND APPROVAL**

### **Declaration by the student**

This thesis is my original work and has not been presented for a degree in any other University or for any other award.

**Signature.....**

**Date.....**

**MERCY MUTHONIWAMBUGU (BSc.)**

**N50/CE/28769/2014**

### **Supervisors:**

**Signature.....**

**Date.....**

**DR. EZEKIEL NDUNDA**

**Department of Environmental Sciences**

**Kenyatta University**

**Signature.....**

**Date.....**

**DR. GLADYS GATHURU**

**Department of Environmental Sciences**

**Kenyatta University**

## **DEDICATION**

To my beloved sons Brian Mwangi, Kenneth Kinyua and Mike Mugo for their continued support during my study.

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## **ABBREVIATIONS AND ACRONYMS**

<b>APHA</b>	American Public Health Association
<b>DAT</b>	Days after transplantation
<b>FAO</b>	Food and Agriculture Organization
<b>GDP</b>	Gross Domestic Product
<b>IPM</b>	Integrated Pest Management

## ABSTRACT

In Asia and West Africa, there is growing evidence of the practicality of using fish into rice production. Nevertheless, locally, in Kenya, have not significantly addressed integrating fish into rice farming for economic and ecological efficiency at Mwea irrigation scheme, Kirinyaga County, thus the necessity for this research to remedy the foreseen research gap. The overall aim of this study was to assess the economic and ecological viability of incorporating fish into rice growing in Kirinyaga County, Kenya's Mwea Irrigation Scheme and specifically; determine the ecological benefit of integrating fish into paddies on rice yield, evaluate the economic benefit of introducing fish into rice paddies, compare the physical-chemical quality of the water in the experimental paddy fields. The research utilized randomized block design in the rice paddies in Mwea irrigation scheme. The investigation included three distinct treatments (each 18m<sup>2</sup> depth with a ditch of 0.5m deep and 1m<sup>2</sup> at its middle). While the very first treatments included rice and stocked with fish fertilized chemical fertilizers, the second one included rice, fish and chemical fertilization and supplementary feeding used for fertilization while the last treatment was maintained as the control containing rice only. Each treatment was in triplicate. Rice seedlings of the Pishori kind were planted in the paddy areas. Fish fingerlings were introduced in the experimental fields fourteen (14) days after rice transplantation at a stocking density of three (3) fish per m<sup>2</sup>. Data on physical-chemical parameters of water was collected and analyzed on weekly basis using the Standard Methods of analysis for examination of water. Data on rice yield and fish was analyzed using quantitative analysis to produce descriptive statistics after three months. The study found that; integrating fish into rice farming has; an economic value of increasing rice yields (by 3.70%) and fish yields (increase by 47.06%) and it as well significantly improves the quality of water. Using ANOVA the study established that phosphates differed statistically across the treatments ( $p=0.647, \alpha=0.05$ ), Nitrate levels varied significantly between the treatments ( $p<0.001, \alpha=0.05$ , independent t-test). Ammonia had a significant difference across the treatment groups ( $p>0.05, \alpha=0.05$ ), Nitrogen had a significant difference across the treatment groups ( $p>0.05, \alpha=0.05$ ), .There were however insignificant difference on temperature between the groups ( $p=0.729, \alpha=0.05$ ), dissolved oxygen had slight significant variation ( $p>0.05$ ), salinity showed narrow variation however the variations were not statistically significant ( $p>0.05$ ), Conductivity levels varied significantly between the 3 treatments ( $p=0.361, \alpha=0.05$ ), a significantly electrical conductivity across treatment group ( $p<0.001, \alpha=0.05$ ), total dissolved solids varied significantly across the groups ( $p<0.001, \alpha=0.05$ ). The study recommends rice farmers in Mwea, Kirinyaga County, Kenya to adopt integrated fish-rice farming. This will diversify their source of income by increasing proficiency in fish farming in their rice farms for more fish yields and increased rice harvest. Farmers will reduce use of chemical pesticides and fertilizers to diversify productivity of the soil. They will also protect the soil by increasing the fish culturing to its optimum, increase their use of biological control of pests and reduce the chemical pesticides and fertilizers to increase the water quality, avoid soil pollution and provide a healthy environment.

## CHAPTER ONE: INTRODUCTION

### 1.1 Background of the Study

Essentially, the Integrated Pest Management (IPM) technique are being extensively used and has been promoted as a feasible method for reducing the adverse impact of pesticides on the environment (Alam.M.Z. *et al.*, 2016). Pests have a number of harmful effects on the environment, including; destruction of food for other species, destruction of habitat for other species.etc. This was after significant evidence suggested that indiscriminate use of pesticides is posing intrinsic health dangers and environmental hazards, raising serious ecological and health concerns (Stadlinger & Kumbilad, 2013). Specifically, intensive and indiscriminate use of pesticides may have significant negative ecological and health impact to the surrounding environment and population where it is used (Abong'o *et al.*, 2014; Kaoga *et al.*, 2013). In an effort to reduce the perceived dangers of pesticides, farmers have utilized biological and ecological methods that are considered environmentally friendly as technological approaches to pest management (Tam, 2016).

Most of the available empirical studies mainly address the effects of pesticide and recommend for controlled usage of chemical pesticides (Balogun & Musa, 2013). As Tam's (2016) study reveals, application of pesticides in farming has negative effects to the environment, it suggests for studies to be conducted on use of integrating fish into rice paddies (Halwart *et al.*,2014). Studies on integrating fish into rice farming have widely been conducted in Asia and West Africa. According to Alam *et al.* (2016) the most ideal technique for assuring high rice yields, safeguarding the environment, and reducing the detrimental effects of pesticides on the ecosystem is the integration of fish into rice cultivation.

Among the IPM approaches are the traditional pest control methods practiced both in developed and developing economies. Integrating fish into rice farming has been propagated as a viable traditional pest control mechanism for irrigation systems (Saikia *et al.*, 2015). Although integrating fish into rice farming has been widely practiced in developed as well as developing countries, it has received a trifling attention in the Africa region. In fact, only a few African countries such as Ghana and Nigeria have actively adopted it (Chebai, 2014). Thus, integrating fish into rice farming has not received the required attention by the irrigation agencies in the East African region

(Ja'afaru *et al.*, 2015). More specifically, integrating fish into rice farming has not received the required attention in Kenyan irrigation systems.

## **1.2 Problem Statement**

In recent years, intensive and indiscriminate use of chemical pesticides for pest control and fertilizers has been witnessed in the Mwea Rice Irrigation Scheme fields (Chebai, 2014). The intensive and indiscriminate use of chemical pesticides might significantly cause soil pollution on the rice paddy fields. These pesticides are most likely to contribute to contamination of drinking water arising from chemical contaminants in these pesticides. In fact, high toxicity of the pesticides highly threatens the health of human population and other living organisms (Kaoga *et al.*, 2013; Abong'o, 2014). Thus, chemical pesticides may pose a danger to the environment we live in (Pretty & Bharucha, 2015). Several studies show that chemical pesticides used in rice irrigation affect public health (Chebai, 2014; Mwangi, 2014). The study by Mwangi (2014) reveals that there is risk on rice being affected by some predictable diseases. Various studies conducted on pest control have recommended for an appropriate action to be taken that would avert the danger of these pesticides use. Most of the studies on integration farming have laid more interest on assessing the economics (Saikia, 2015) and ecological efficiency (Freed *et al.*, 2020) and social benefits (Ja'afaru *et al.*, 2015). These studies have still not gone into detail about the economic and environmental benefits of incorporating fish into rice growing in the Mwea Irrigation Scheme.. Further Alam *et al.* (2016) study recommends for the need to conduct further research on IPM methods for creation of a sustainable rice agro ecosystem.

Knowledge among Kenyan farmers about negative effect of these pesticides is generally low (Abong'o *et al.*, 2014). Again, most of the related studies, conducted in Kenya have laid more emphasis on assessing the consequences of using pesticides rather than examining a viable economic and ecological pesticides control mechanism (Saikia, 2015). Nevertheless, these studies have laid little emphasis on economic and ecological mechanism of integrated farming that would supersede the negative effects of chemical pesticides. Thus, there is insignificant research on incorporating fish into rice growing in irrigation schemes as a pesticide replacement, leaving a knowledge gap. This prompted the current research, which aimed to close the gap.

### **1.3 Objectives of the Study**

The study was guided by the specific objectives:

#### **1.3.1 General Objective**

The general objective of the present study was to assess the economic and ecological viability of integrating fish into rice farming as an alternative to chemical pesticides at farms in Mwea Irrigation Scheme, in Kirinyaga County, Kenya

#### **1.3.2 Specific objectives**

The study was guided by the following specific objectives:

1. To determine the ecological benefit of integrating fish into paddies on rice yield
2. To evaluate the economic benefit of introducing fish into rice paddies
3. To compare the physical- chemical quality of the water in the experimental paddy fields.

### **1.4 Research questions**

1. What is the economic benefit of introducing fish into rice paddies?
2. What is the ecological benefit of integrating fish into paddies on rice yield?
3. How does rice fish introduction affect the water quality in the paddy fields?

### **1.5 Research Hypotheses**

The study will seek to test the following hypotheses:

1. H<sub>0</sub>: Integrating fish into rice farming is not significantly economically viable.
2. H<sub>0</sub>: Integrating fish into rice farming is not significantly ecologically viable.
3. H<sub>0</sub>: Integrating fish into rice farming does not significantly affect physical-chemical quality of water

### **1.6 Significance of the Study**

Apparently, the research will provide valuable information in its findings which would be beneficial to various stakeholders including; farmers of rice in Mwea irrigation scheme, policy makers in the agricultural sector, government of Kenya rice producers,

general public, academicians and researchers. The study would be useful to the farmers of rice in Mwea irrigation scheme and other rice producers in gaining information on means of achieving economic gain from fish-rice production system. It might enable the farmers to make informed decisions regarding the appropriate use of integrated fish rice farming as they desist from intensive and indiscriminate use of pesticides on their rice farms. By so doing, it might lessen the environmental impact of chemical pesticides on rice farm and generate profits to the farmers. Thus, the integrated fish-rice farming might lead to diversified livelihoods to the population. Because the combined fish-rice farming system is non-destructive to the environment, its use at irrigation schemes could help conserve water, plant, and animal genetic resources..

The outcomes of the research will be useful to agricultural policymakers who are trying to figure out how to increase their income while also addressing the environmental issues that come with rice growing. Fish feed requirements and the use of artificial fertilizers would be reduced if fish-rice cultivation were integrated. The fish waste product might serve as fertilizer for the rice paddy fields. Thus, the farmers would access free fertilizer and reduce use of chemical fertilizers and pesticides, e.g. pesticides that controls apple snails.

The adoption of integrating fish into rice farming approach is important to governments of Kenya (both national and county) in the formulation of aquaculture policies for economic growth of the country. As a result, the increased income created by the widespread adoption of integrated fish rice farming will contribute to poverty alleviation as well as the country's economic and social development.

Importantly, the study would be of help to the rice producers when making decisions on diversifying farming It should however be noted that rice is the main product (crop) of the paddy fields. Economically, integrating fish into rice farming might be used as tool for hunger eradication, fighting poverty and eliminating malnutrition (Mwangi, 2014). Because of its rapid growth rates, high-quality flesh, disease tolerance, adaptation to a variety of production systems in tropical to temperate climates, and capacity to thrive and reproduce in captivity, tilapia is known as "aquatic chicken." Such are suitable at temperatures of 23-35°C with our area experiencing temperatures of between 20-26°C. The tilapia fingerlings are easy to acquire as the research was done

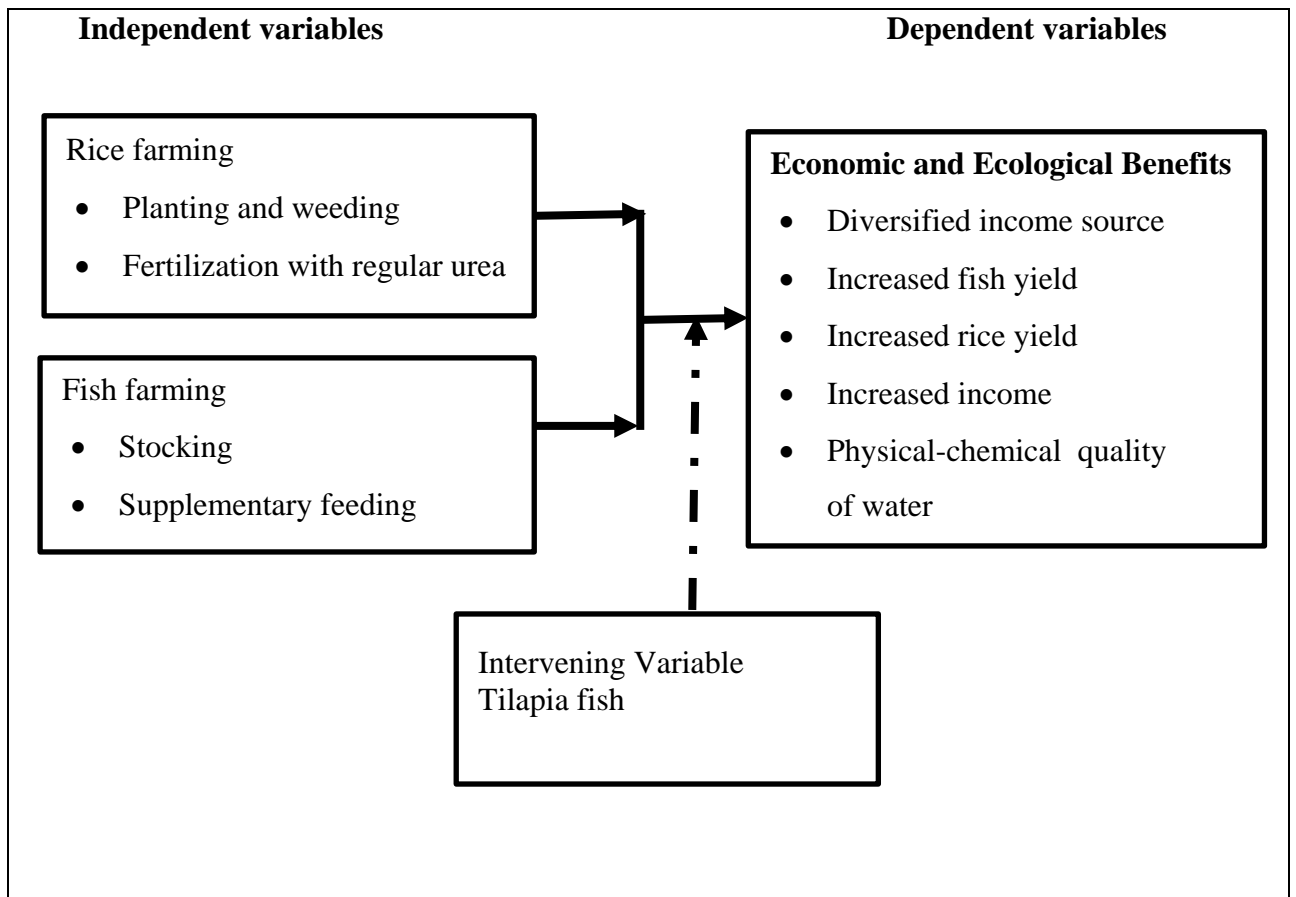
close to the Sagana Aquaculture Centre. This approach would also aid in the reduction of pests in the paddy fields.

The findings would be important to the Kenyan population in seeking to free itself from hunger and even being healthy since integrated rice-fish farming potential play the most active participation in hunger eradication as well as fighting poverty and malnutrition. The study would add knowledge in the field of IPM, making the results beneficial to experts , policy makers and partners.

The present brought new knowledge about integrating fish rice farming at Mwea Irrigation Scheme. This makes it useful to academicians and scholars seeking for knowledge in rice-fish aquaculture and mitigating challenges occasioned by chemical pesticides and fertilizers. It therefore opened a window for more research on integrating fish rice farming, benefiting prospective researchers as well as scientists in this field. Thus, the report would be used as a reference tool for future exploration by researchers..

### **1.7 Conceptual framework**

The study independent variable is rice farming while its dependent variables in this case are the economic and ecological benefits like increased crop and fish yields, increased growth in fish size, reduced use of chemicals to control pest, improved soil, and water quality among others as captured in Figure 1. The intervening variable is the fish farming, which was integrated as an alternative pesticide control. The main goal/output of this study was to have effective land management in order to achieve economic sustainability with minimal damage to the environment.



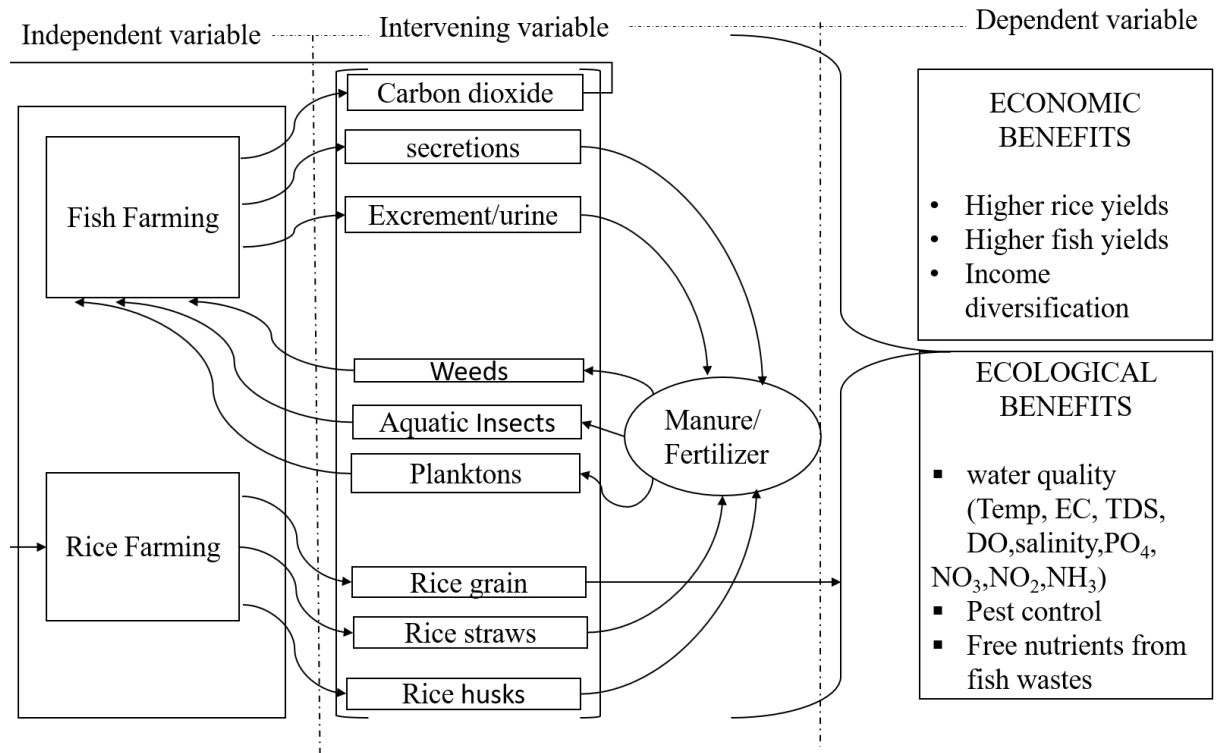
**Figure 1.1: Conceptual Framework**

The proposition by the study was that introduction of fish into rice paddy fields results into additional nutrients generated in the rice cycle, positively benefiting the rice growing in terms of soil fertility. Thus, integrated rice fish culture might be highly profitable for small scale rice farmers by having higher yield of paddy grain. This also enriches the ecosystem through provision of a condition for both rice and fish to be cultivated together concurrently. Also, the fish stocked in the rice paddy fields feed on the organisms in the paddy such as worms, larva & aquatic weeds, which accelerates fish growth and as well biologically control the population of rice pests.

According to the study, the physical properties of the soil might be altered when the fish move around in the rice paddy field. Further, the soil pores in the rice paddies are raised when fish is in the production season rod using culturing of the fish. Therefore, the bioturbation by fish might increase soil aeration and fertility as it inhibits growth of weeds. The rate of dissolved oxygen in the soil is increased as a result of fish movement.

In paddy field soil recovery, it also elevates the risk of soil oxidation, thereby improving the content of oxygen in the soil and the intensity of nutrients hidden within the soil of the paddy fields.

The study model is shown in Figure 1.2



**Figure 1.2: Study model**

## **1.8 Definition of Terms**

**Aquaculture** is the farming of aquatic organisms, such as fish, practised in marine environment and underwater habitats (Abrol 2014).

**Fish culturing** is artificial propagation and breeding of fish (Halwart & Gupta, 2004)

**Fish stocking density** is the mean weight of the fish at the time of stocking (Balogun *et al*, 2014)

**Growth of the fish** is the increase in fish length and weight, higher survival rate, high growth rate and increased net production (Baba *et al.*, 2013)

**Integrated fish rice farming** is the concurrently or sequentially farming rice and stocking fish in the same paddy fields, of which at least one is aquaculture (Food and Agriculture Organization [FAO], 2016).

## **CHAPTER TWO: LITERATURE REVIEW**

### **2.1 Introduction**

This chapter summarizes the literature that was reviewed for the purpose of the study based on theories and empirical studies. Thus, the chapter covers theoretical framework overview and empirical literature of empirical studies. For the empirical studies, the chapter cover the findings and recommendation by various authors in addition to showing the research gap that the present study filed.

### **2.2 Theoretical Review**

This study reviews various theories found useful in bringing light to the current study. The theories found helpful in the present study are; integrated pest management theory, theory for biodiversity and ecosystem, and the trap-and-crop theory. These theories assisted in the development of the study conceptual framework.

#### **2.2.1 Integrated Pest Management Theory**

The integrated pest management theory proposes that tactics that mitigate insect pest damage in agricultural settings, since pest management has replaced pest eradication as the goal of mitigating crop damage; yield loss (Bottrell & Schoenly, 2018). A key tenet of pest management is that low levels of pest activity are tolerable (Coll & Wajnberg, 2017)). The theory proposes that pest mitigation tactics such as pesticide applications are warranted, only after pest populations reach an economic threshold. In this regard, IPM programs, such as integrated fish in rice farming, are essential for efficient and economical pest management (Bottrell & Schoenly, 2018). A cost-benefit analysis is the foundation of any IPM program). In order for the cost benefit analysis to be effective, it should include not only the control cost, cost associated with implementation, and crop value, but also crop response to pest activity (Pretty & Bharucha, 2015).

#### **2.2.2 Theory for biodiversity and ecosystem**

Theory for biodiversity and ecosystem emphasizes using ecosystem services for biodiversity conservation and for benefiting the society (human beings), where it takes the position of a key tool for informing and guiding natural resource management

(Duffy, Godwin & Cardinale, 2017). According to the theory, people through indirect interactions may link different ecosystem services which also directly affect each other (Hagan, Vanschoenwinkel & Gamfeldt, 2021). In the case of the present study, the rice fertilization ecosystem services and pest control using fish stocking interact indirectly when the bioturbation by fish increase soil fertility and directly when the level of pest control affects fertilization or vice versa (Freed *et al.*, 2019). Interactions, both direct and indirect, between these ecosystem services have important practical implications for combined management of integrated fish culture and rice culture (Berg & Tam, 2018).

Based on the theory for biodiversity and ecosystem, the introduction of fish into rice farming, fish increase soil fertility through their secretions that increases the fertilization of the rice and hence increases the rice yields. This is based on the rice fertilization ecosystem services. The fish bioturbation increases, which increase the fish weight and quantity. Thus, the introduction of fish farming into rice farming increase productivity of both the fish and the rice crop hence increased income from the approach.

Using the theory, then integrating fish into rice farming enhance and ecological benefit to the environment where the approach is employed. The theory also talks about guiding natural resource management which in respect to the present study, it avoids soil corruption and provide an environment which is not harmful to human beings and other living population. Importantly, based on theory, the integrating fish into rice farming would ensure undisturbed environment with regards to water quality. This helped the current study regards the physical- chemical quality of water as a factor leading ecological benefits of integrating fish into rice farming.

### **2.2.3 The Trap-and-Crop Theory**

The Trap-and-Crop Theory emphasizes on the development of an aquaculture system for human entrepreneurial benefit (Walelign, Jiao & Smith-Hall, 2020). According to the theory, the humans create traps and fences for allowing fish and crustaceans to be trapped and are easily harvested (Haider *et al.*, 2018). On the aquaculture context, the theory posts that the fish that have entered the traps are allowed to grow, over time, to a larger size. In respect to the present study, the fish integrated into the rice paddy fields were allowed to grow over the period of rice growth (up to harvest time). Based on this

theory, integrating fish into rice farming is like trapping the fish in the rice field, which then allows the trapped fish to grow in size. The growth of the fish implies that there will be higher sales from the harvest and more income. Thus, the theory informs on the importance of introducing fish into rice farming in terms of returns and income. Thus, the trap-and-crop theory provided useful information of the importance of trapping fish in rice paddies for increased harvest and increased income. This helped the current study consider the economic aspects of integrating fish into rice farming in the current study..

## **2.3 Empirical Review**

The present study reviewed literature related to fish rice culture which was found useful in explaining the adoption of integrating fish into rice farming for economic and ecological efficiency at Mwea Irrigation Scheme, Kenya. The present study reviewed past studies on; harmful effects of pesticides, ecological impacts of integrating fish into rice farming, economic viability of the activities and ecological impacts of integrating fish into rice farming, and increased rice production and the level of fish yield.

### **2.3.1 Harmful effects of pesticides**

The study by Yeboah (2013) found that the indiscriminate use of pesticides causes intrinsic health dangers and environmental challenges as Tam (2016) study showed. The study by Tam also showed that use of pesticides negatively affects climbing perch living in rice fields and therefore recommends for use of ecological principles that would enhance ecosystem biodiversity and productivity rather than through intensified use of pesticides. The local study by Abong'o *et al.* (2014) showed that indiscriminate use of pesticides was associated with fatalities such as reduction of; pollinating insects and wild birds such as Red-billed Oxpecker as well as fatalities on wild birds. Abong'o *et al.* (2014) study further established that farmers had limited knowledge on risky nature of chemicals pesticides, safety measures required, and associated chronic illnesses. Indeche and Ondieki-Mwaura (2015) confirmed the findings in the study by Abong'o *et al.* (2014) in the study.

### **2.3.2 Economic Viability and Environmental Impacts of Rice-Fish Farming**

Studies have assessed the economic viability and minimization of negative impacts on the environment of integrated fish in rice farming. For instance, Dubois et al. (2019) found that on integrating fish into irrigation infrastructure projects, there are considerably more protein and micronutrients available from the fish produced in the system. Should these farming system innovations be adopted at scale, there is a significant opportunity for water planners and managers to create win-win solutions by incorporating integrated farming systems such as rice-cum-fish culture in the command area of water control infrastructure.

Freed et al. (2020) found that integrated and agro ecological rice-fish production practices can contribute to productivity and income for small-scale food producers and to ecosystem maintenance and capacity for adaptation to climate change and natural disasters. Alam *et al.* (2016) conducted a study that found that the use of IPM effectively; protects the environment, leads to high rice yields and it creates a more sustainable agro-ecosystem.

In their investigations, Berg and Tam (2018) revealed that rice-fish integrated systems can maintain/increase rice output all the while delivering a variety of other benefits. Converting irrigated paddy fields to combined rice-fish farming has significant potential for Myanmar's agri-food sector while adapting to or minimizing the effects of climate change and enhancing resource efficiency.

While findings show that small indigenous species and other aquatic creatures and plants that benefit from a pesticide-free environment, Islam et al. (2015) discovered that rice-fish farming boosts households' food and nutrition security by providing them with a source of fish, a highly nutritious diet. Households who practiced integrated farming ate more fish and had a larger proportion of fresh fish in their menu.

Baba *et al.* (2013) found that integrated fish- rice farming ensures water use maximization and contributes to drastically reducing chemical pesticides utilization at Golinga Irrigation Project in Ghana as it enhanced incomes from sales of both commodities. The study by Pretty and Bharucha (2015) established that use of IPM, delivers a wide range of economic benefits. Studies such as by Baba *et al.* (2013) and

Munguti and Ogello (2014) found that there is limited knowledge of modern aquaculture technology and there is incomprehensive aquaculture policy in Kenya.

Certain studies have established that adoption of integrated fish- rice farming increase rice production, generate additional fish and increase income. For instance, the studies by Desta (2014) and according to Saikia et al. (2015), cultivating native fish in waterlogged rice fields would strengthen the rural livelihoods through community involvement. Pengseng (2013) study found that adoption of fish into rice farming increase rice production, increase fish yield and increases farmers' income. Other studies revealing the same findings are those by Zira *et al.* (2014), Kumar, Chari and Vardia (2012). Berg, et al. (2012) argue that more options for different systems helpful for preserving and expanding a wide range of ecosystem services and protecting human health in agriculture should be made available. The study recommended that future production methods be adjusted to assure the provision of interconnected ecosystem services including rice, fish, pest control, and nutrient recycling.

### **2.3.3 Economic and Ecological Viability and Environmental Impacts of Rice-Fish Farming**

Several studies have been conducted to analyze the economic viability and environmental impact of integrated fish in rice cultivation.. Baba *et al.* (2013) found that integrated fish- rice farming ensures water use maximization and contributes to drastically reducing chemical pesticides utilization at Golinga Irrigation Project in Ghana as it enhanced incomes from sales of both commodities. The study by Pretty and Bharucha (2015) established that use of IPM, delivers a wide range of economic benefits. Studies such as by Baba *et al.* (2013), Noorhosseini-Niyaki and Bagherzadeh-Lakani (2013), conclude that integrated fish- rice farming has socio-economic benefits as well as numerous biological and ecological effects. The studies revealed the benefits of this approach traverse over increase in productivity of the soil as well as soil protection. It also revealed increased nutrients uptake, biological control of weeds, biological control of pests as well as drastically reducing chemical pesticides utilization (Allahyari &Noorhosseini, 2014). In the study by Munguti and Ogello (2014) it was found that there is limited knowledge of modern aquaculture technology and there is incomprehensive aquaculture policy in Kenya.

Numerous research works also have studied and appraised the benefits of adopting ecological systems as an alternative to the harmful chemical toxins.. Dubois et al. (2019) found that Myanmar could gain from improved employment, earnings, and nutritive quality of farm fields (together with accompanying pesticide pollution reductions) as well as reduced water use. Myanmar must take steps to build an enabling business and environmental policy, notably in terms of making provisions for moving land usage from paddy to other agricultural purposes in order to enable this transition. However, it appears that the seeds of change have been sown, and with the wise use of water. Myanmar has a unique chance, according to Dubois et al. (2019), to promote the well-being of a growing population while keeping up with the country's rapid development of economy.

According to Joffre et al., (2018), encouraging rice-shrimp approaches that restrict nutrient discharge and reestablish connectivity between the plot and the larger ecosystem should help to offset some of the environmental and health risks associated with high-input farming.

According to Islam et al. (2015), there are changes in integrated rice fish farming systems that support ecological integrity and biodiversity protection while also providing a wide range of nutrition and livelihood advantages, in line with a holistic view of sustainable food systems.

Alam et al. (2016) points that more research on biological techniques for creating a sustainable rice agro-ecosystem is needed.

The study by Halwart *et al.* (2014) established that stocking carp fish in rice paddy highly reduced the snail densities regardless of carp stocking density, and the rate of predation of the carp increased with increased level of snail infestation. The study found that Nile tilapia significantly reduced the densities of snail and particularly during the dry season and when the fish stocking density was high. Balogun, Aliyu and Musa (2014) conducted a study which also showed that the use of IPM for pest control results into sustainable environment, increased economic income and ensures food security.

Noorhosseini-Niyaki and Bagherzadeh-Lakani (2013) conclude that integrated fish-rice farming has socio-economic benefits as well as numerous biological and ecological effects. The studies revealed the benefits of this approach range from an increase in

productivity fertility of the soil as well as soil protection. It also revealed increased nutrients uptake, biological control of weeds, and biological control of pests as well as drastically reducing chemical pesticides utilization

#### **2.3.4 Water quality**

Based on research work by Binh et al., (2018), climate change, freshwater accessibility, and quality of water are currently the major issues for Vietnam's rice and fish sectors. Even while rice-shrimp growers report using fewer pesticides and antibiotics than intensive shrimp producers, semi-intensive rice-shrimp cultivation can discharge alien species, nutritional burdens, and anti-biotic and agrochemical residues (Braun et al., 2019).

#### **2.4 Research Gaps**

The studies in other countries have shown that integrated farming has immense ecological and economic benefits; for instance, integrating fish into rice farming has been associated with; increased rice yield, fish growth, increased incomes, and drastic reduction in utilization of chemical pesticides. However, numerous studies showed that integrating fish into rice farming was a viable approach in Asia, West Africa and developed countries. Most of the studies conducted in Kenya did not provide sufficient evidence of the ecological and economic benefits of integrating fish into rice farming. In fact, there is scanty information on integrated fish-rice farming in Kenya as being associated with economic and ecological benefits, a gap the present study seeks to find

#### **2.5 Conclusions**

The present study reviewed theories found useful in development of a study conceptual framework and empirical studies related to it. At a glance, the theories showed that use of integrated farming has economic as well as ecological benefits. The study further reviewed empirical research, which showed that integrating fish into rice farming has economic benefit and that introducing fish into rice farming has ecological benefit since integrating fish into paddies affects physical- chemical quality of the water.

## **CHAPTER THREE: METHODOLOGY**

### **3.1 Introduction**

Prominently, the present chapter discusses the research methods utilized in this analysis, including the original study location, research design, research populations, sampling of population, gathering of data, equipment and procedure use, and data analysis methodologies..

### **3.2 Study Area**

#### **3.2.1 Location**

With regards to study locale, the current research took place in the Mwea irrigation project, which is located in Kirinyaga County, Kenya just along Embu-Nairobi Highway, and some 100 kilometers from Nairobi. Thi scheme is located at an elevation of 1,175 meters above sea level and spans a total area of about 30,350 acres; is situated between Latitude 0<sup>0</sup>30' and 0<sup>0</sup>45' South and Longitudes 37<sup>0</sup>14' and 37<sup>0</sup>30' East, as shown in Figure 2. The scheme lies at the confluence of rivers Nyamindi, Murubara and Thiba.

#### **3.2.2 Climate**

A total of 950mm of rain falls on the system each year. Long rains come in April and May, and short rains fall in October and November, creating a bimodal rainfall pattern (Indeche & Ondieki-Mwaura, 2015). Rice is sown during brief rainstorms with temperatures above 170°C..

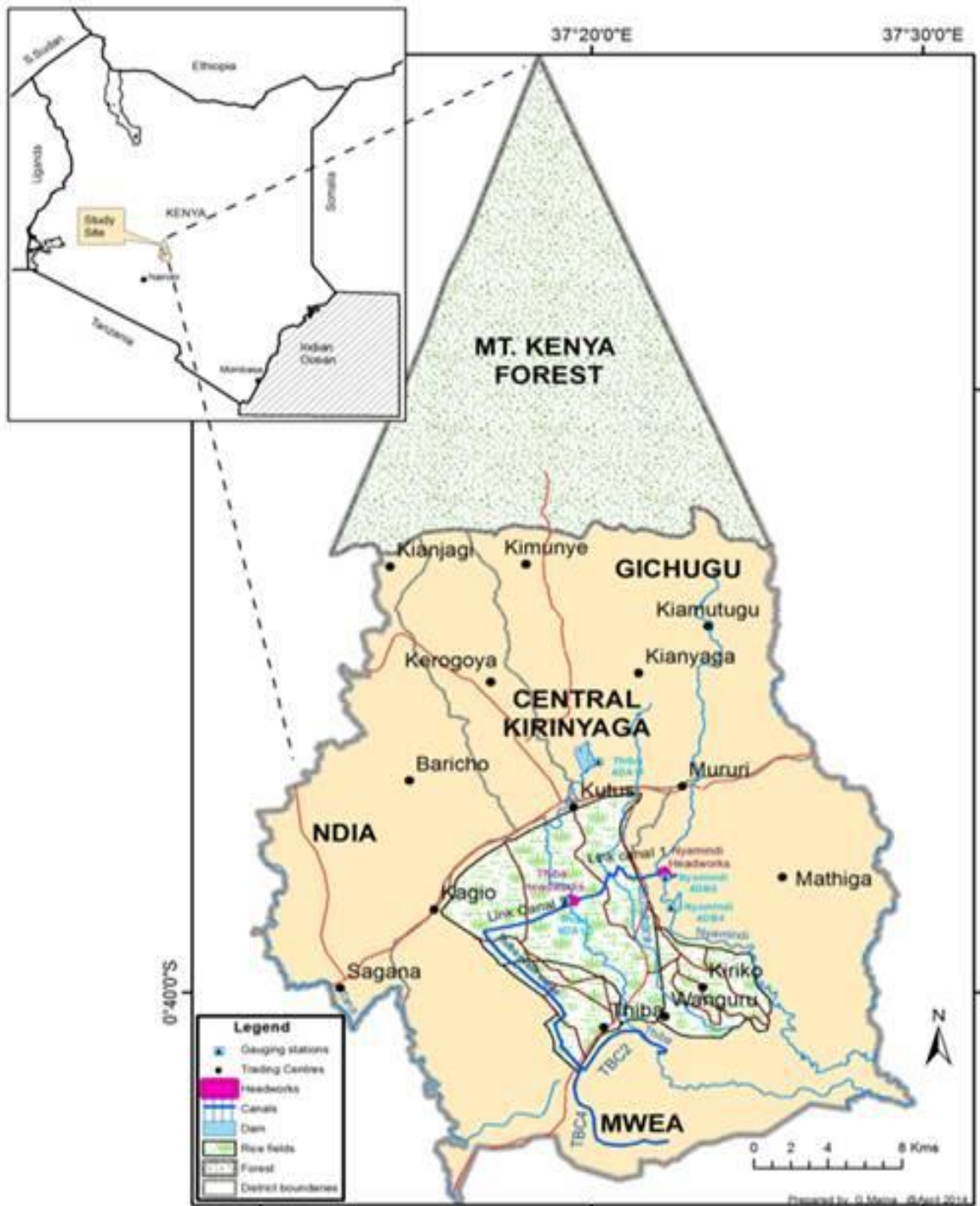
#### **3.2.3 Physical features**

The overall topography at Mwea irrigation Scheme is uniform with relatively flat plain, which makes irrigation to be done by gravity. The water comes from the slopes of Mt. Kenya flowing at river Thiba, River Nyamindi and River Murubara., then to rice fields through canals.

Soils consists of lateric clay loam (red soil) and montmorillonite clays, with about 80% clay or black cotton soils (Indeche & Ondieki-Mwaura, 2015).

### **3.2.4 Economic Activities**

While in the Mwea irrigation program, rice farming is the main source of revenue, other economic activities include business, production of other crops, such as maize, onions, beans, kales, tomatoes and French beans. Farming has led to the growth of conventional businesses, such as welding, grain milling, retail shops, wholesale shops, as well as financial services. There has been steady growth in infrastructure and emergence of numerous market centers.



**Figure 3.1: Map of Mwea Sub-county**

(source: Government of Kenya, 2013)

### 3.3 Research Design

During the analysis in the current work, experimental research design was adopted because it offers the best method to study randomly selected groups due to the high degree of control. The treatment in experimental plots were randomly allocated

(Randomization) into the different groups. Samples of rice and fish were randomly selected, a significant feature of experimental research design (Asiamah, Mensah, & Oteng-Abayie, 2017). The study used true experimental design, completely randomized block design (Mishra & Alok, 2017). In the research, experiment consisted of three (3) distinct treatments, each of which was replicated 3 times. The first treatment (Treatment I) included rice that had fish and fertilizers, including Urea, Di-Ammonium Phosphate (DAP), Triple Superphosphate (TSP), and Mureate Phosphate (MP) were used. Next, the second treatment (Treatment II) included rice and fish with partial fertilization (DAP and MP) and fish supplied with supplementary feeding. The third method of treatment (Treatment III which had rice only was used as a control. Table 3.1 contains a summary of these.

**Table 3.1: Design and layout of the experiment**

Combinations of rice, fish		Inputs	
		Feed	Fertilizer
T1	Rice + Fish	-	Urea, DAP& MP, TSP
T2	Rice + Fish	Feed	DAP& MP, TSP
T3	Rice only	-	Urea, DAP & MP, TSP

The ratios of fertiliser concentrations were; 2:1:1 for Di-Ammonium Phosphate (DAP), Mureate Phosphate (MP) and Triple superphosphate (TSP) respectively. Fertilizers were put 1.25cm from the roots of the plants

### 3.3.1 Land preparation

The bush on the land was cleared. The dykes were then prepared using mud that was compacted in order to hold water in the paddies. Each paddy measured 3m width and length of 6m. The paddy is as shown in appendix III. The central ditch measured 1m by 1m and a depth of 0.5m. Tilling was done using a “*jembe*” and ditches dug at the

center of the six paddies at random. The paddies were then flooded with water for one day in order to soften the soil and then drained. This water was supplied by Sagana fisheries, which has a research centre in Sagana, Kirinyaga County. The soil was then leveled using a wooden stick. The paddies were then flooded with water for 2 days and then drained to loosen the soil. The land was now ready for planting.

### **3.3.2 Seedlings preparation**

Half kilogram of unprocessed pishori rice was soaked in water for three days. Soaked rice was put in a sack and buried in the soil for two days. This was done in order to aid the rice to root. After rooting, it was broadcasted on the well-prepared nursery as shown in appendix II, and left to grow for one month. DAP fertilizer was added to the seedlings on the second week after broadcasting. The seedlings were then transplanted into the paddies after one month. The study used pishori rice because this plant was found to be very effective in the area of the study. This rice was transplanted when it was about 7 cm long, 30 days after broadcast. It should be noted that the weeds were not analyzed since they were not part of the study. However, there was normally weeding to keep the paddies free of weeds. Also, the study was not interested in the height of the rice but the yield from the rice crop. The fish was feeding on the invertebrates egg apple snail. These invertebrates were the pests affecting the rice and the introduction of the fish was to get rid of those pests.

### **3.3.3 Fish fingerings preparation**

Nile Tilapia fingerings were obtained from Sagana Fisheries, two weeks after transplantation. Initial length and weight of fish were taken and recorded as shown in appendix IV. The fingerlings were then packed in plastic bags containing water and oxygenated using pump( appendix V). This was done to enable the fish reach to their destination (experiment site). At the site, the fish fingerlings were acclimatized by mixing the water from the paddies with that in the polythene bags carrying the fish as in shown in appendix VI, then introduced into the paddies. All the paddies containing fish were covered with nets to prevent predators from accessing the fish.

The choice of Nile Tilapia over any fish was based on the fact that it is largely herbivorous, with aquatic macrophytes, algae, and diatoms accounting for over 90% of its diet and aquatic insects, crustaceans, and fish eggs accounting for the remainder

(Pretty & Bharucha, 2015). Pests in paddy fields would be reduced as a result of this. Because of its rapid growth rates, high-quality flesh, disease tolerance, adaptation to a variety of production systems in tropical to temperate climates, and capacity to thrive and reproduce in captivity, tilapia is known as "aquatic chicken.". They are suitable at temperatures of 23-35°C with our area experiencing temperatures of between 20-26°C. The tilapia fingerlings are easy to acquire as the research was done close to the Sagana Aquaculture centre. Fish and rice were left to grow for three months ( appendix VII), after which the data was collected.

### **3.3.4 Water analysis**

In-situ measurements were taken on water from all the nine ponds including pH, dissolved Oxygen, Temperature, Electrical conductivity, Total Dissolved Solids, Turbidity and Salinity.

Samples were collected from all the paddies and taken to the Central Water Testing Laboratory, (Nairobi) for physical-chemical analysis. The parameters tested in the Laboratory were; Total Nitrogen, Total Phosphorous, Phosphates, Nitrates, Nitrites, and Ammonia and the results recorded. This was done before planting, after planting and on monthly intervals. The rice fields In this exercise, the weeds were not sampled because the study was interested in the fish growth and rice yields. All the treatments were equally attended to with weeding done as it was usually done during normal rice tending.

### **3.3.5 Rice Treatment**

Two weeks after transplanting, fertilizers were applied as follows;

Paddy 1, 3, 5(T1), 2,4,6(TIII) were applied 221g of Urea and 221g of DAP per rice paddy.

Paddy 7,8,9(T2) were applied 221g of DAP per pound. Where Paddies 1,3and 5 were for treatment I, Paddies 7,8 and 9 were for treatment II, and paddies 2,4 and 6 were for treatment III. Two weeks after rice transplantation, the paddies were flooded and fish fingerings introduced into the central ditch in treatment I and II. When the rice was about to mature, MP fertilizer was added to all the paddies at a rate of 221g per paddy. Fish in treatment II were fed with fish feeds on daily basis. Observations on fish growth

and rice were made as rice and fish progressed in growth. When rice was mature and ready for harvesting, all the water was drained from the paddies and fish harvested from the central ditches. The yields from different paddies were obtained and recorded.

### **3.4 Sample size and Sampling Procedure**

In this research, the experiment was carried out during 2017-2018 planting season. Each of the nine experimental plots covered an average of 18m<sup>2</sup> and had a ditch of depth of 0.5m and covering an area of 1m<sup>2</sup> excavated in its middle for providing shelter to fish especially when the water levels were low or when the temperatures were high. The researcher also constructed water channels for supplying water to the experimental plots, each having a width of 70 cm and a depth of 30 cm. The researcher also constructed embankments of 0.5m high and 0.50 m wide, surrounding these plots, to exclude flood water. Each of the dykes had water depth regulated by having a common inlet and outlet.

To keep undesired animals out of the plots, the researchers utilized nylon nets fastened to bamboo splits around each one. Two out-lets were installed to drain surplus rain water from the raising plot area, which were guarded by a 5mm mesh size screen at the field water intake and a 10.0 mm mesh size screen at the rearing plot's main water gate to keep wild fish and aquatic predators outside the rice paddies. The trenches and paddy plots were filled with irrigation water.

After growing for a month in the nursery, Pishori seedlings variety of high yield rice plants were transferred into the paddy field. Advance fingerlings of Nile Tilapia (*Oreochromis niloticus*) were released in the center ditches fourteen (14) days after transplanting (DAT) of rice seedlings at a stocking density of three fish per m<sup>2</sup>. The average weight of the fish was measured and recorded, and the water level was raised to 10cm two weeks later. The fish was provided by the Kenya Marine and Fisheries Research Institute (KMFRI) in Sagana, Kenya..

### **3.5 Data Collection**

All data for this analysis was gathered from primary sources. The researcher gathered information on fish in terms of weight at harvest, quantity of fish and survival of fish for each plot (T1 and T2). Data on rice production on each plot (T1, T2 and T3) were

collected after harvesting and recorded on the data sheet. The fish were caught using a net and all the fish in treatment weighed using a digital scale and then counted. By dividing the weight by the number of fish in each treatment, the weight per fish was calculated. Data on income generated from sales of fish as well as expenses on fish culturing was collected. Water samples for assessment of Carbon dioxide (CO<sub>2</sub>), alkalinity, Ammonia, Phosphate and Nitrates were collected from the nine plots between 9am and 10am and then taken to laboratory for physico-chemical analysis and recorded. Conductivity, temperature dissolved oxygen (DO), and pH were all measured in the water using digital probes at the site ( multi-parameter kits).

Rice was cultured for 128 days while the Fish was cultured for 90 days upon which it was harvested 2 weeks prior to rice harvesting in Treatments I and II.

### **3.6 Data Analysis**

In this study, descriptive statistics were created using a quantitative analysis analysis to explain the qualities and characteristics of the study variables. The study initially generated descriptive statistics, such as frequencies, means, standard deviations, and percentages, to summarize the findings of the analysis. Mean (M), Standard deviation (SD), Minimum (MIN) and Maximum (MAX) were the primary descriptive statistics employed in the study.

The research began by determining the economic feasibility of incorporating fish into rice growing by first measuring the fish growth in the rice paddies. The researcher measured; fish weight, survival rate, growth rate, and net production. At harvest, fish were weighed and the population density estimated per pound. The total profit obtained from fish farming was calculated using the formula

$$\text{Total profit from fish farming (Kshs)} = \text{Total financial return (Kshs.)} - \text{Total financial cost (Kshs)} \dots\dots\dots(i)$$

Next, the study calculated economic viability on paddy rice yield to establish the production of rice based on rice yields and income from rice farming (total income/net return). The study compared the average rice yields from experimental and control plot.

Income gained in terms of profit was also determined based on the formulae:

Profit gained (Kshs) = Revenue collected (Kshs.) – Cos of operations (Kshs)  
.....(ii)

$$\text{Profitability} = \frac{\text{Total Profit (Kshs)}}{\text{Expenditure–Total cost (kshs)}} \times 100 \dots\dots\dots (iii)$$

The research started by determining the ecological viability of incorporating fish into rice production by measuring water protection. The chemical composition of the water was documented when it was analyzed. The total nitrogen and accessible phosphorus in the water were measured (Bremner & Mulvaney, 1982). pH, temperature, dissolved oxygen, total nitrogen, total dissolved solids, conductivity, Nitrites, total orthophosphate ammonia, and nitrate nitrogen were all measured in the paddy water (American Public Health Association [APHA], 2005). The Winkler method was used to calculate the dissolved oxygen. The Ion Selective Method was used to assess ammonia, while the Photometric Method was used to determine nitrates-nitrogen, nitrites, and phosphorus, all of which were determined using standard methods for the investigation of water and waste water (APHA 2005).

Further, the study teste the hypothesis in section 1.5 using one way ANOVA

## **CHAPTER FOUR: RESULTS AND DISCUSSIONS**

### **4.1 Introduction**

Results obtained after analysis of gathered data, data produced from analysis as well as interpretations and discussions were presented in this chapter. The main contents of the chapter are the descriptive statistics as well as its discussions of these results and hypothesis testing. The descriptive statistics contain results on; performance of fish culturing, economic benefit of integrating fish into rice fields, growth of fish and physical- chemical properties. The hypothesis testing produced results on significance of integrating fish into rice and on physical- chemical properties of water quality and also on significance of integrating fish into rice on fish growth.

Throughout discussions of the outcomes, this analysis referred to the literature examined in Chapter 2 in its arguments, where it made reference to empirical investigations as well as theoretical evidences. Importantly, the study objectives as well as research hypotheses influenced these discussions. These talks offered enough data to extrapolate the findings to the total population..

### **4.2 Descriptive Statistics**

The outcomes of the analysis of the various characteristics of research variables are captured in this portion of the study. The main contents of the section are results on the performance of fish culturing, economic benefit of integrating fish into rice fields, growth of fish and physical- chemical properties.

#### **4.2.1 Analysis on economic benefit of introducing fish into rice paddies**

The evaluated the economic benefit of introducing fish into rice paddies which was assessed and the results captured in this section This was done by comparing the total yield of both fish and rice with that of monoculture (rice only).

The results on the performance of the fish and among the three treatment was captured in Table 4.1.

**Table 4.1 Analysis by Performance of fish culturing**

<b>Stocking data</b>	<b>Treatment I</b>	<b>Treatment II</b>	<b>Treatment II</b>
Stocking rate	150	150	-
Average size at stocking	14.4g	14.4g	-
Average size at harvesting	44.2g	65g	-
Survival percentage	83%	90%	-

Founded on outcomes in Table 4.1, while fish stocking density was 14.4g in both treatments, while the average size of harvest in treatment I was 44.2g, the average harvest in treatment II was 65g. this shows that treatment II had a higher production rate than treatment I. So, the production of fish in rice with feeding has higher yields than production of fish in rice fields with feeding. The rate of increase was 20.8 (65-44.2) kg which translate to an increase of 47.06%. Founded on these results, survival rate of fish in treatment I was 83% and that in Treatment II was 90%. It may be concluded that feeding fish in rice fields increases survival rate of the fish since fish in rice fields with feed had higher survival rate than fish in rice fields without feeding.

As captured in Table 4., the study provided an analysis on cost incurred during the experiment and the results on total costs of production breakdown.

**Table 4.2 Analysis by cost of production**

<b>Item</b>	<b>Unit cost(Ksh)</b>	<b>Units</b>	<b>Total Cost</b>
Labour for clearing bush and digging cost	700	Block	700.00
Construction of paddies	700	Block	700.00
Rice for seedlings	150	0.5	75.00
Planting cost	400	block	400.00
Fertilizer DAP and MP	140	.663x3	185.00
Urea, 663g per treatment	160	.663x3	106.00
Fish fingerings	10	300	3,000.00
Fish feeds, 60g per day	400	12g	810.00
Labour for harvesting	300	Block	300.00
	<b>Grand Total</b>		<b>6,276.00</b>

Informed by outcomes in Table 4.12, the total experiment cost was Ksh.6276.00. This included the cost of the material (rice, fish, chemicals) and labour (preparation, construction, planting, feeding and harvesting)

Accordingly, Table 4.3 capture the research obtained the data after harvesting, which was used together with the cost of the experiment (Table 4.2) to compute cost and benefit analysis, which was captured in.

**Table 4.3 Cost - Benefit analysis of integrating fish into rice paddies**

<b>Item</b>	<b>Treatment I</b>	<b>Treatment II</b>	<b>Treatment II</b>
<b>Production (Total Kgs harvested)</b>			
Rice	14kg	16.8kg	16.2
Fish	5.5kg	8.8kg	-
<b>Operating costs</b>			
1. Fish fingerlings (Kshs)	1500	1500	-
2. Rice seeds (Kshs)	25	25	25
3. Fertilization DAP& MP (Kshs)	185	185	185
Urea (Kshs)	106	-	106
4. Fish Feeds (Kshs)	-	810	-
5. Labour(Kshs)	2100	2100	1,850.00
<b>Total costs</b>	<b>3916</b>	<b>4,620.00</b>	<b>2,166.00</b>
<b>Returns</b>			
Rice (Kshs)	1,960.00	2,352.00	2,268.00
Fish(Kshs)	2,200.00	3,520.00	-
<b>Total returns</b>	<b>4,160.00</b>	<b>5,872.00</b>	<b>2,268.00</b>
Net returns	244.00	1,252.00	102.00
<b>% Net returns to operating costs</b>	<b>6.20%</b>	<b>27.10%</b>	<b>4.70%</b>

The total production of rice as depicted in Table 4.3 was, 14Kg, 16.8Kg and 16.2Kg for treatments I, II and III respectively. Treatment I produced a somewhat lower rice yield than the other rice-fish culture fields and Treatment III. When the fish production was taken into consideration, however, it was discovered that the net returns across the systems differed, with Treatment I having higher net returns than the control. The change in rice yields between treatments II and III was 0.6 (16.8 -16.2), resulting in a 3.70 percent gain. According to Zira et al. (2014) and Kumar, Chari, and Vardia (2012), including fish into rice farming increases rice output, which is consistent with the current report's outcomes.

There was a substantial increase in rice yields in treatment II, which was attributed to improved aeration of soil and water due to fish movement, increased soil fertility as a result of fish excreta and reduced insect pests which were controlled by fish as they also fed on insects. The study by Alam *et al.* (2016) found that the use of IPM effectively; protects the environment, leads to high rice yields and it creates a more sustainable agro-ecosystem. The study by Alam *et al.* (2016) suggests for further research biological methods for creation of a sustainable rice agro-ecosystem. The findings in the present study confirm the study by Alam *et al.* (2016). Balogun, Aliyu and Musa (2014) conducted a study, which also showed that the use of IPM for pest control results into sustainable environment, increased economic income and ensures food security.

#### **4.2.2 Analysis by growth of fish over period of the study**

The study captured the results on the progression in the growth of fish, in terms of length (cm) and weight (gms) in treatment I and II, over the period of the study. This is where Table 4.4 portrays data at different sampling periods under two treatments of the experiment.

**Table 4.4 Analysis by growth of Fish in length and weight**

Time of sampling	Treatments			
	Treatment 1		Treatment 2	
	Length(cm)	Weight (gms)	Length(cm)	Weight(gms)
<b>Jul-18</b>	8.60±0.17 <sup>b</sup>	14.4±0.84 <sup>a</sup>	8.6±0.17 <sup>a</sup>	14.4±0.84 <sup>a</sup>
<b>Sep-18</b>	9.84±0.20 <sup>b</sup>	19.35±0.60 <sup>a</sup>	10.2±0.18 <sup>a</sup>	26.5±0.95 <sup>b</sup>
<b>Oct-18</b>	11.7± 0.37 <sup>b</sup>	34.0±0.69 <sup>b</sup>	12.8±0.25 <sup>b</sup>	46±1.31 <sup>c</sup>
<b>Nov-18</b>	12.2±.18 <sup>b</sup>	44.2±0.61 <sup>b</sup>	16.4±0.15 <sup>d</sup>	65±1.52 <sup>d</sup>
<b>P-value</b>	<0.001	<0.001	<0.001	<0.001

*Mean±SE (Standard Error) followed by the same small letter within the same column do not differ significantly from one another (SNK-test,  $\alpha=0.05$ )*

In the month of November 2018, at the end of the ninety-day (90) testing phase, fish in treatment II attained average weight of 65g while fish in treatment I attained an average weight of 44.2g. The maximum average length attained by fish in treatment II was 16.4cm, while that attained in treatment, I was 12.2cm. The study showed that rice fish integration would therefore increase the yield of fish. These findings agree to studies by Desta (2014) and Saikia *et al.* (2015) which cultivating native fish in wet rice fields would strengthen the rural economy by means of community engagement. Pengseng (2013) study found that adoption of fish into rice farming increase fish yield and increases farmers' income, which was true in this study.

The fish were seen to have a growth rate of 0.46g per day in treatment I while Treatment II had a growth rate of 0.67g per day. This was attributed to feeding the fish in treatment II with artificial feeds while the ones in treatment I had to depend on phytoplankton and zooplankton.

The market price for fish was 400/= per kg while rice was sold at 140/= per kg. The total fish production from treatments I and II was 5.5kg and 8.8kg as shown in table 4.2 respectively. The mean fish size obtained from the experiment was 65.62g, whereby the locals consider undersized because they are accustomed to larger fish weighing over

150 g. Quantity of fish at harvest could have been influenced by factors such as stocking size, rice field culture period, and the amount and quality of supplementary feed.

According to the findings in Table 4.2, urea administration increases the production of rice and aquatic weeds that fish eat. Early estimations suggested that rice-fish farming would require 50 percent to 100 percent more fertilizer than rice farming without fish (Baba et al., 2013), with the extra fertilizer believed necessary to sustain phytoplankton formation as the foundation of the intensive aquaculture food supply chain. According to recent research findings, the inclusion of fish in the rice paddy might greatly increase rice field productivity and reduce fertilizer requirements as evidenced by the fact that no additional fertilizer was required in the Treatment I.

The study by Halwart et al. (2014) established that stocking common carp in rice paddy highly reduced the snail densities regardless of carp stocking density, and the rate of predation by the carp increased with increasing level of snail infestation. The research also discovered that Nile tilapia lowered snail densities dramatically, especially during the dry season and when fish stocking density was substantial.

The total fish yields for Treatment I were 5.5kg per 18m<sup>2</sup> and 8.8kg . Fish yields range from 50 kilograms per hectare to 2.25 tons per hectare, depending on a variety of parameters including nation, fish species, density, fish diets, culture tenure, and a range of additional factors (Leelapatra *et al.*, 1992; Li, 1992). In our study we noted that our catch was around 50kg/ha due to the stocking density of 3 fingerlings per m<sup>2</sup> and period of study which was 90 days.

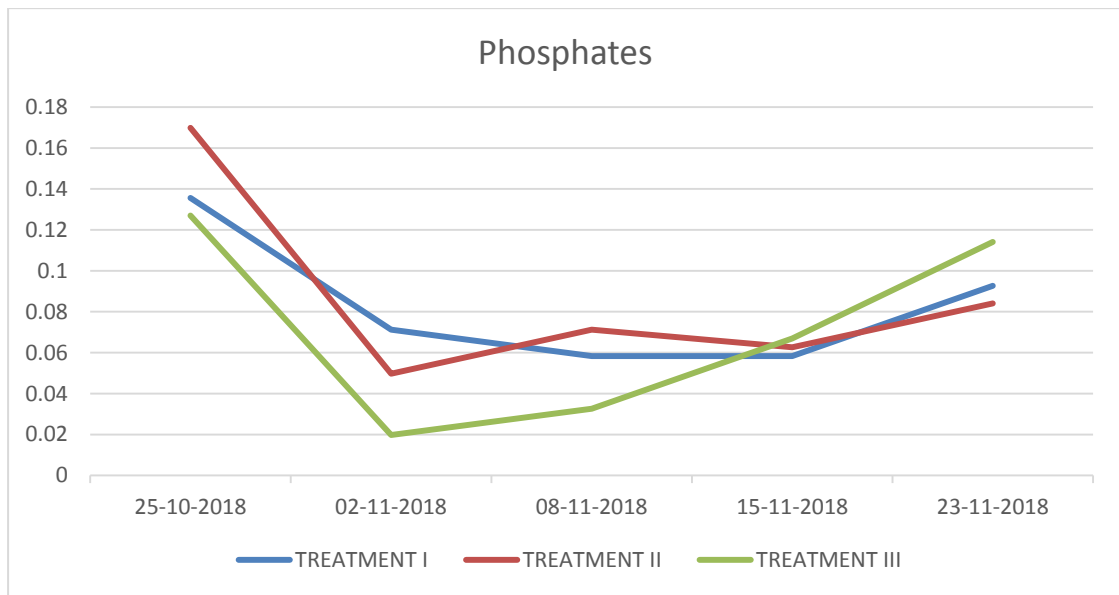
The survival rate was 83% and 90% for treatment I and II systems respectively indicating good management and suitability of Nile tilapia for rice integration system.

#### **4.2.3 Analysis by Physical- chemical quality of the water in the three treatments**

On analysing the physical- chemical properties of water quality based on Phosphate, Nitrates, Nitrites, Ammonia, Nitrogen, hydrogen, Total dissolved solids, Electrical conductivity, Dissolved oxygen, and Temperature, , Salinity and outcomes are summarized in this section in that order.

##### **4.2.3.1 Phosphates analysis**

The results on status of phosphorous are in figure 4.1



**Figure 4.1 Phosphates concentration**

A short time after the experiment was started, the data on phosphates was analysed showing treatment I and treatment II as recording 0.01 mg/L each. Meanwhile treatment III recorded 0.05mg/L. In treatment I, it increased and stabilized at 0.03mg/L. In treatment II, phosphates, which was first recorded at 0.05mg/L, dropped to 0.02mg/L and then increased to 0.05mg/L. In treatment III, it stabilized at 0.01mg/L for a while before increasing to 0.02mg/L. It can be observed that the phosphates levels first decreased in all treatments in the first month which can be attributed to uptake by rice after which it began increasing in Treatment II and III. In all treatments. In treatment I the fish took longer to grow out thus began increasing the soil porosity which led to the eventual increase in Phosphates levels much later than those in treatment II which took a shorter period to grow due to the feeds used. Plots lacking fish had higher soil porosity attributed to the prevalence of undisturbed oligochaetes.. This explained why the final Phosphates levels in Treatment III were higher than those of treatments I and II.

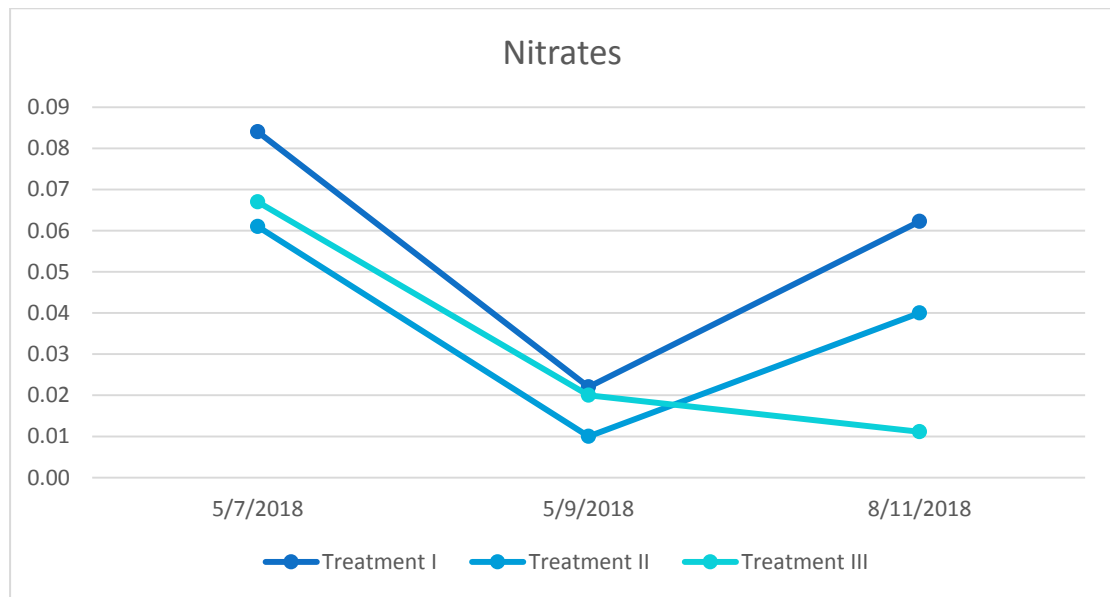
Phosphorus is useful for providing energy to growing plants. Lack of phosphorus leads to stunted growth of plants. In treatment III Phosphates improved from 0.01mg/l to 0.01mg/l and then fell to 0.002mg/l throughout treatment I, but maintained at 0.03mg/l. Phosphates in treatment II fell from 0.05mg/l to 0.02mg/l before rising to 0.05mg/l.

Fish have an impact on the phosphorus cycle as well. According to Halwart and Gupta (2004), phosphorus is frequently a major limiting factor for primary production since it

is often fixed in the soil and unavailable to plants in the rice field. Fish, by disrupting the soil, enhance soil porosity and facilitates phosphorus transfer to the soil..

#### 4.2.3.2 Nitrates concentration

Figure 4.2 shows the level of nitrate concentration across the period of the study



**Figure 4.2 Nitrates concentration in the three treatments**

In treatment I, the Nitrates ions were 0.08mg/L at the start of the experiment. These reduced to 0.02mg/L and then increased to 0.06 mg/L mid-way. Meanwhile, the Nitrates ions in treatment II were recorded as 0.06 in the start of study, reducing to 0.01mg/L and then increasing to 0.04mg/L. The behavior of the Nitrate ions in the Treatment III was different from the rest. While in treatment I and Treatment II, the ions decreased and then increased, in treatment III these decreased from 0.07 mg/L to 0.02mg/L and then to <0.01mg/L. The Nitrates were within the recommended WHO level.

Based on results in Table, for each treatment Nitrates concentration (mg/l) is <0.1 except for cases where there was water only. There was a pond that neither contain rice nor Nile Tilapia but had water. In this pond the nitrates concentration (mg/l) varied between 0.193 mg/l and 0.530 mg/l. this implies that there was presence of nitrates in the water which was used in the study. The Nitrates concentration in the other ponds

(treatments) was low a factors that is attributable to the presence of rice. Notably rice roots contribute Nitrogen fixation since they have symbiotic (contain rhizobia bacteria) relationship with bacteria. The rhizobia bacteria break down Nitrogen compounds to produce Nitrates which are assimilated by the plants and more specifically the rice, helping the rice to grow hence depletion of Nitrates concentration. Since the rice and other plants (such as weeds) are using the Nitrates, then the level of Nitrates concentration reduces drastically. However, due to the use of fertilizers (urea) in the ponds, the concentrations ought to have been greater in treatment III..

The Nitrates in control plots (treatment III) continually decrease from 0.07 to 0.02 and then to 0.01, implying that there was considerable growth of rice, which demanded for more Nitrates hence the reduction of the Nitrates.. As the rice grew, it used most of the available Nitrates. Under Treatment I, the Nitrates dropped from 0.08 to 0.02 and then drastically increased to 0.06 while in treatment II the Nitrates decreased from 0.06 to 0.01 and then abruptly increased to 0.04. This implies that the fingerlings were stocked during the month of July 9<sup>th</sup> 2018 so in by July 18<sup>th</sup> 2018 they were still maturing, implying that the ammonia excrete was low. The rice used the available Nitrates in the water causing a drastic decrease in the Nitrates. Initially the water had Nitrates, which was used by the rice. Over the month of September 2018 the fingerlings matured (fingerling took about three months to mature) and would therefore produce ammonia excrete, which caused the abrupt increase of Nitrates in the treatment plots.

#### **4.2.3.3 Analysis by Nitrites levels**

The levels of Nitrites across the treatment did not differ significantly ( $p = 0.122$ ,  $\alpha = 0.05$ , One-way ANOVA). The levels of Nitrite were  $0.05 \pm 0.01$  mg/L,  $0.04 \pm 0.00$  mg/L and  $0.04 \pm 0.00$  mg/L for treatment 1, treatment 2 and treatment 3 respectively. Results on nitrites concentration are in Table 4.5.

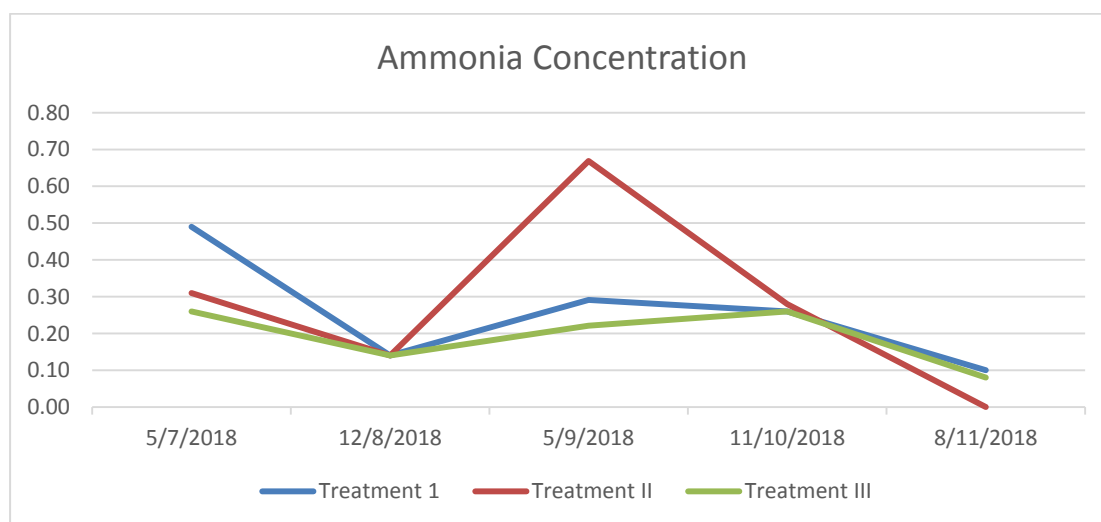
**Table 4.5: Mean Nitrite concentration (mg/l)**

	<i>Nitrite concentration (mg/l)</i>		
	05/07/2018	05/09/2018	08/11/2018
Treatment I	0.04	0.05	0.05
Treatment II	0.04	0.05	0.04
Treatment III	0.03	0.04	0.04

The levels of Nitrites across the treatment did not differ significantly ( $p = 0.122$ ,  $\alpha = 0.05$ , One-way ANOVA). The levels of Nitrite were  $0.05 \pm 0.01$  mg/L,  $0.04 \pm 0.00$  mg/L and  $0.04 \pm 0.00$  mg/L for treatment 1, treatment 2 and treatment 3 respectively.

#### 4.2.3.4 Analysis by Ammonia concentration

Results on Ammonia concentration (mg/L) are captured in figure 4.3



**Figure 4.3: Ammonia concentration (mg/L) across the treatments**

The results show that the behavior of ammonia in the three treatments was similar. For each of them it decreases then increased, and started decreasing. In treatment I the

changes were such that the ammonia concentration, initially at 0.49mg/L decreased to 0.138mg/L, increased to 1.16mg/L then started decreasing. It went to 0.026mg/L and dropped further to 0.10mg/L. The ammonia concentration in treatment II was initially 0.31mg/L dropping to 0.143mg/L and then increasing to 0.67mg/L and decrease to 0.28mg/L. It then decreased to less than 0.01mg/L. The ammonia concentration in Treatment III was 0.26mg/L immediately after the experiment was started and decreased to 0.14mg/L the following sample collection. However, it increased to 0.26mg/L through 0.20mg/L and then it dropped to 0.08mg/L. The patterns of fluctuations of the ammonia concentration in the three treatments were closely similar.

Halwart and Gupta (2004) In the rice field, ammonia (NH<sub>3</sub>) is a significant source of nitrogen. Ammonia is relatively safe to Nile Tilapia in its ionized form, NH<sub>4</sub><sup>+</sup>, but severely toxic in its unionized form, NH<sub>3</sub>. The percentage of the various forms is affected by the pH of the water, with the NH<sub>3</sub> concentration increasing by a factor of ten for every unit increase in pH between pH 7 and pH 9. (Roger, 1996). As a result, when the pH of the water reaches high levels, the ammonia concentration in the water can kill Nile Tilapia and other creatures, especially after applying nitrogen-rich fertilizer to the rice fields. The concentration of unionized ammonia (NH<sub>3</sub>) in pond water must be kept under 0.5 mg/L.. In all treatments, the levels were maintained below 0.5mg/L. Concentrations higher than this, which is toxic to Nile Tilapia, are influenced by the amount of Dissolved Oxygen, pH, and alkalinity.

The results of Ammonia concentrations in the test ponds showed that for each treatment there was decrease in Ammonia concentration in; Treatment I (M=0.138), Treatment I (M=0.143), and Treatment I (M=0.140) during the first month of the study. In treatment I and II, there was a decrease because the fingerlings were still maturing, rendering the plants to consume the available ammonia as was the case with Nitrates. Due to Nitrogen fixing bacteria present, the level of Ammonia decreased. This was because of the nitrifying bacteria which converted the Ammonia into Nitrogen and maintained the Ammonia concentration levels below 0.5mg/L. The Ammonia concentration drops as the pH dropped from September to November. In treatments, I and III the amount of Ammonia was low throughout due to the presence of Nitrogen fixing bacteria. Treatment II had no Urea fertilization. The ammonia levels were thus high in Treatment II than in Treatments I and II which were fertilized and thus had nitrogen fixing bacteria which maintained the ammonia concentration levels.

#### 4.2.3.5 Analysis by Total Nitrogen concentration

Total Nitrogen is the sum of total ammonium, Nitrates and Nitrites. Since these (ammonium, Nitrates and Nitrites) were each measured individually we summed their totals to get the total Nitrogen in the treatments where table 4.6 holds the obtained outcomes.

**Table 4.6: Analysis by Total Nitrogen**

	TOTAL NITROGEN (mg/L)		
	05/07/2018	05/09/2018	08/11/2018
Treatment I	0.61	0.36	0.21
Treatment II	0.41	0.73	0.08
Treatment III	0.36	0.28	0.13

In the period of the experiment, the total Nitrogen was observed to decline in all treatments. Treatment II though was exceptional in that it experienced a sharp increase in the month of September before reducing to 0.08mg/l by the end of the experiment.

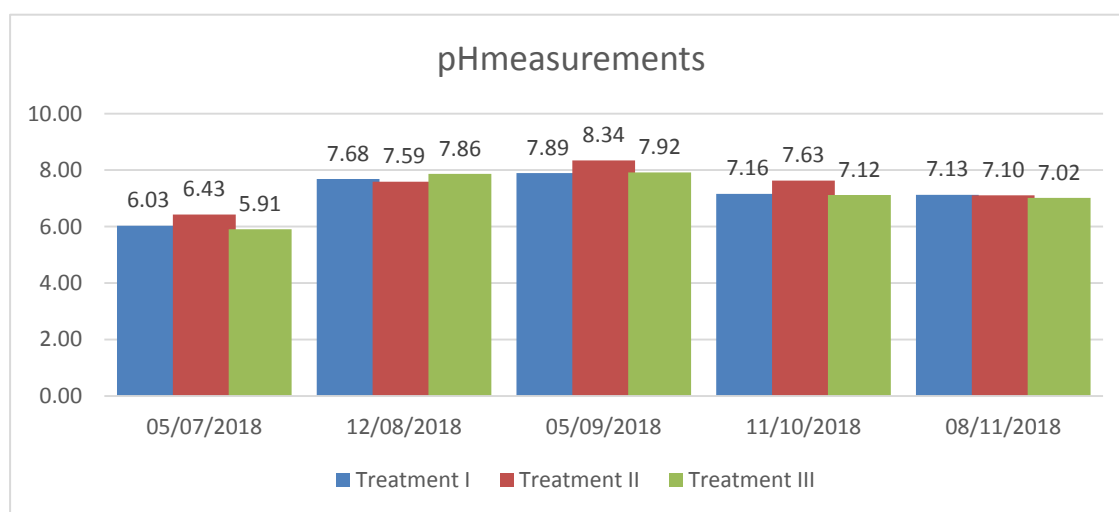
Total Nitrogen levels were greater in Treatments I and II, which contained fish, that influence the Nitrogen cycle in a rice field. Cagauan et al. (1993) discovered that a rice field with fish had a greater capacity to create and capture nitrogen than a rice field without fish. At the same time, fish may aid in nitrogen conservation by reducing photosynthetic activity (through grazing on photosynthetic aquatic biomass and increasing turbidity), so maintaining a lower pH and minimizing ammonia volatilization. Other water properties were also analysed and importantly pH of the water was analysed to

#### 4.2.3.6 Analysis by potential of hydrogen (pH) in water

Other water properties were also analysed and importantly pH of the water was analysed to obtain the results in table 4.4.

The pH levels showed a narrow range of variation between the different treatment groups, with the highest ( $7.47 \pm 0.19$ ) mean pH recorded in treatment group 2 and the lowest ( $7.14 \pm 0.19$ ) in treatment group 1. However, there was statistically insignificant difference in pH between the treatments ( $p = 0.361, = 0.05$ ).

The study's goal was to compare the pH levels of the three treatments over the course of the trial as shown in Figure 4.4



**Figure 4.4: Graphical presentations of pH measurements**

### Research data (2019)

All the results of treatment I and treatment II show that the pH was within the desired limits of between 6.0 and 9.0. Although there were fluctuations, none of the recordings in these treatments violated the locally recognized pH levels. For instance, treatment I started at 6.03 to 7.68 then 7.89 dropping to 7.16 and then to 7.13. In treatment the results show that it started at 6.43 increasing to 8.34 through 7.59 and then reduced to 7.63 before dropping to 7.10. In treatment III as the pH recording show an initial value of 5.91, they also show that it increased 7.86 before reaching 7.92 and then dropped to 7.12 before decreasing to 7.02.

Normally, pond water pH should be kept between the ideal limits for Nile Tilapia, which are 6.5 and 8.5. Respiration consumes oxygen and generates carbon dioxide ( $\text{CO}_2$ ), which, when dissolved in water, makes carbonic acid ( $\text{H}_2\text{CO}_3$ ), which dissociates into bicarbonates ( $\text{HCO}_3^-$ ) and carbonates ( $\text{CO}_3^{2-}$ ). As a result, hydrogen

ions ( $H^+$ ) are released, increasing the acidity of the water and causing the pH to fall. Carbon dioxide is also produced in the atmosphere by natural diffusion and agitation of surface water, as well as by the decomposition of organic materials. The removal of  $CO_2$  from the water as a result of photosynthetic activity, on the other hand, causes the hydroxyl ions ( $OH^-$ ) to increase, raising the pH of the water (Halwart & Gupta, 2004).

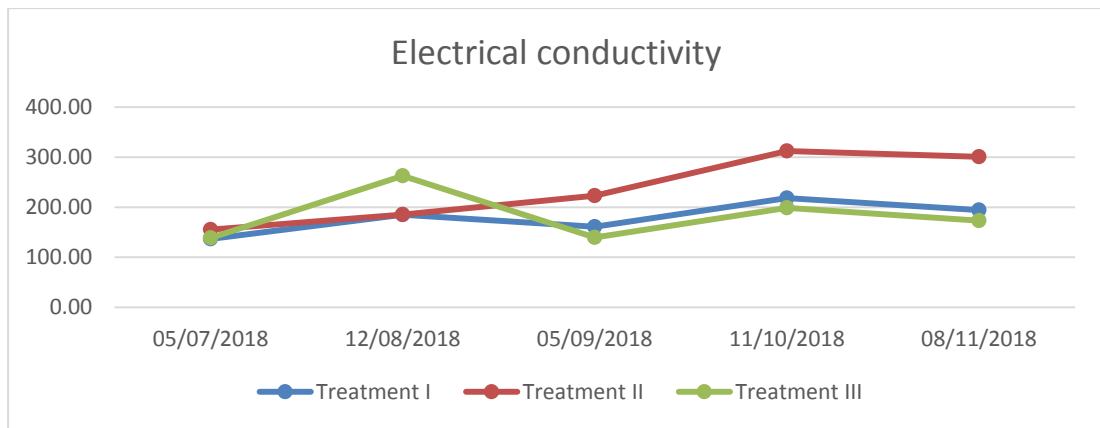
For each of the treatments, pH increased in the first three months and then started decreasing. The pH in treatment I, II and III increased steadily from July to September 2018 and decreased gradually from September to November. The increase and eventual decrease in pH was due to fluctuation in the amount of dissolved oxygen which has a positive correlation to pH. Between September 2018 and November, the pH slightly decreased as amount of dissolved oxygen decreased.

It can also be observed that in treatments III, and I the pH gradually increased from July to September then gradually decreased from September to November and can be attributed to the introduction of urea fertilizer during the early stages of rice growing which increased the alkalinity of the water and gradually decreased as the rice grew. The highest levels were experienced in Treatment II since no urea fertilizer was used.

#### **4.2.3.7 Electrical conductivity**

Ideally, total dissolved solids and electrical conductivity are inextricably linked. The property of water to transmit electricity was created by ions from dissolved minerals in the water. Conductivity of the water was measured using potentiometric method. Notably, treatment II contained both fish and rice. Fish feeds were introduced into treatment II. The study may therefore associate the higher electrical conductivity in treatment II to the presence of feeds and fish rice paddies and state that at 5% significance level, (one way ANOVA), There is sufficient proof to show that fish and food in rice paddies have a considerable favorable impact on electrical conductivity .

This is explained by the behavior of electrical conductivity as captured in figure 6 below.



**Figure 4.5: Electrical Conductivity**

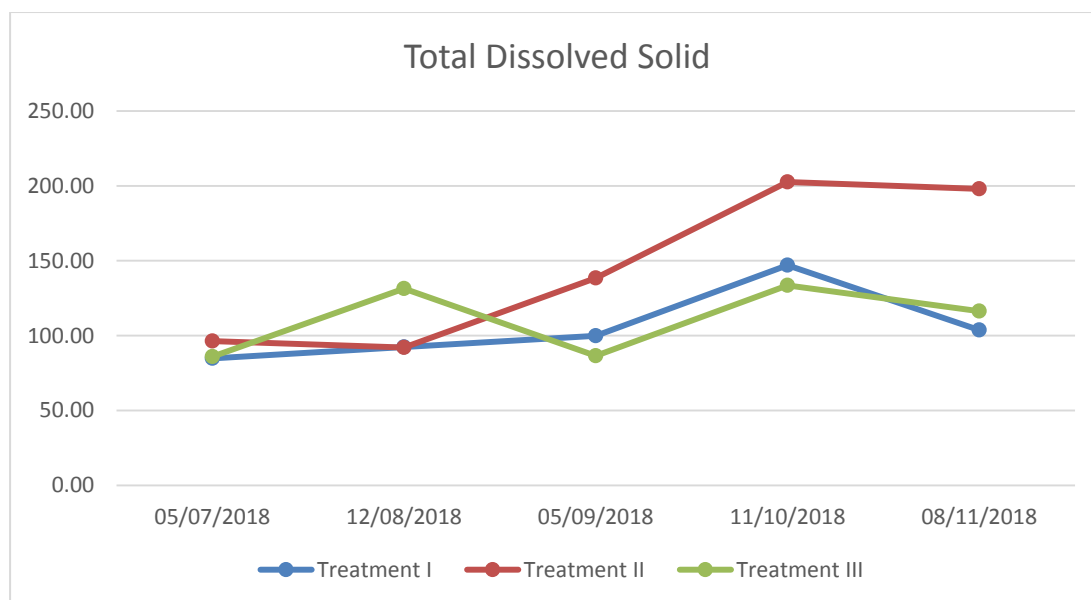
All the measurement showed fluctuations in each treatment with treatment I recording an increase from 136.30µS/cm to 185.00µS/cm then decrease to 161.09 µS/cm before increasing to 218.31µS/cm and dropping to 194.36µS/cm. The results showed that electrical conductivity in treatment III had a consistent increase from 155.30 µS/cm to 183.33µS/cm then to 312.08µS/cm before dropping to 300.66µS/cm. The fluctuations in treatment III were consistent with those in treatment I since it started at 138.67µS/cm, increased to 262.78 µS/cm and then dropped to 139.49µS/cm and increased to 198.76µS/cm finally dropping to 173.29µS/cm.

Fundamentally, electrical conductivity is a metric for determining the concentration of ions or salts in water by determining how well it conducts electricity. Water with a high conductivity has a good buffering capacity in general. This is measured in Siemens (S) per centimeter at 25°C and fluctuates with temperature. If the electrical conductivity of the water is between 100 and 300 S/cm at 25°C, it is considered ideal for Nile Tilapia cultivation.. In our three treatments, we observed that the electrical conductivity for all the treatments was between those ranges with the exception of Treatment II on the 11/10/2018 and 08/11/2018.

Electrical conductivity is also used as a measure of fish contamination with levels above 300µS/cm observed to have a high concentration of heavy metals which end up contaminating the fish. The levels of conductivity in our treatments were all within acceptable limits of electrical conductivity thus indicating that the fish were not contaminated. Without specialized equipment, these measures were used to analyze fish protein for contamination.

#### 4.2.3.8 Analysis by Total dissolved solids

Total dissolved solids, which contributed to conductivity were measured and tabulated in the figure below



**Figure 4.6: Total Dissolved solids**

The results show consistency in the changing nature of the total dissolved solids among the three treatments. The total dissolved solids were shown as increasing for greater part on the initial stages of the experiment before drastically dropping. In Treatment I, the total dissolved solids were recorded as 84.73ppm increasing to 92.33ppm, 99.8ppm and then to 147.03ppm before dropping to 103.72ppm. The recording in treatment II show that the first level of total dissolved solids as 96.28ppm, which increased to 92.00ppm before increasing to 138.48ppm and then 202.61ppm and dropped to 197.96ppm. In treatment III the first recordings of total dissolved solids were 85.97ppm then increased to 131.33ppm and dropped to 86.49ppm which then increased to 133.47ppm before dropping to 116.29ppm.

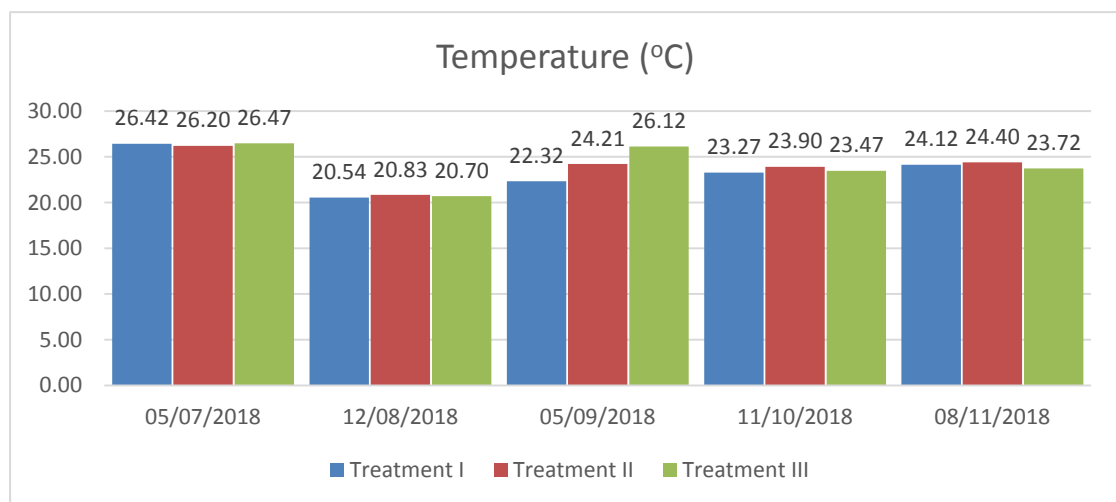
Total dissolved solids (TDS) mean the total amount of chemical ions dissolved in a body of water. Total dissolved solids and electrical conductivity are inversely proportional. Water's ability to conduct electricity is caused by ions from dissolved substances in it. This is normally controlled by the source of pond water and nearby

land use. Measurements of above 1000mg/L indicate a water quality problem. As observed in the graph below we notice that the curves of the linear graphs are almost identical to those observed in the Electrical conductivity graph for all treatments although the measurements are different. The TDS affects the electrical conductivity as increase in TDS led to an increase in Conductivity and vice versa

#### 4.2.3.9 Temperature analysis

The results showed that the changes in water temperature in the three treatments as similar in treatment II and treatment III.

The temperature was also measured for various days that yielded results in figure



**Figure 4.7: Graphical presentation of temperature (°C)**

Treatment did not vary considerably from the rest. In treatment I the temperature which started at 26.42°C dropped to 20.54°C before increasing to 22.32°C and then to 23.27°C settling at 24.12°C.

For treatment I, there was drop to 20.54°C from 26.42°C before increasing to 22.32°C and then rising to 23.27°C, which then increased to 24.12°C. Treatment III which experienced a similar pattern as treatment II was shown as dropping to 20.70°C from 26.47°C before increasing to 26.12°C and dropping to 23.47°C and then to 23.72°C.

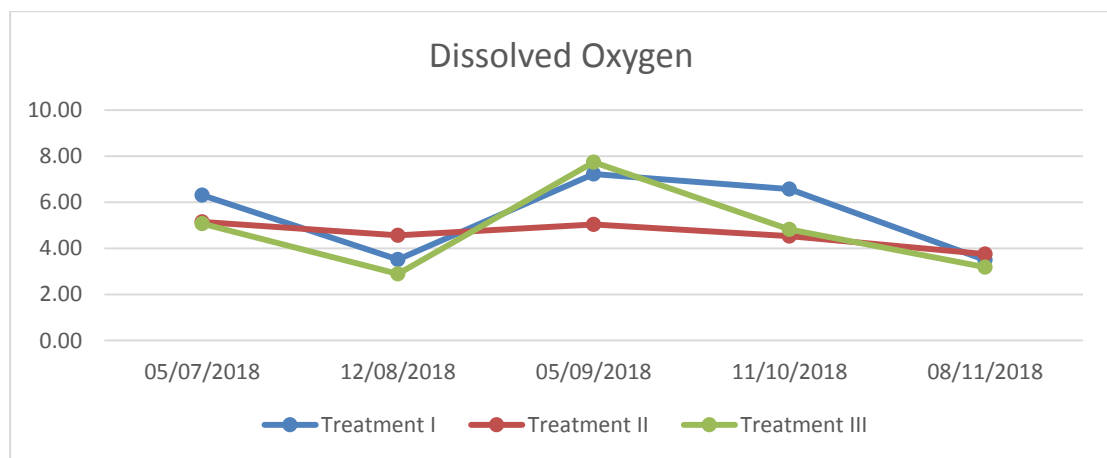
Rice, according to Halwart and Gupta (2004), demands water and soil temperatures of approximately around 40°C, with daily temperature changes of up to 10°C, with no negative effect on development while Nile Tilapia (*Oreochromis niloticus(L)*) can be

cultured in areas with temperatures between 25°-35°C. Stable temperatures with daily fluctuations of up 4°C were observed these were between 20°C and 26°C maintaining the Nile tilapia metabolic rates. The temperatures were on the lower side with averages of between 23°C and 24°C recorded. The diurnal temperature changes were frequently around 4°C, and they decreased as the rice canopy density grew. The temperature conditions fluctuated evenly across the treatment indicating the presence of the fish had little to no effect on it. This can be attributed to the geographical location of the pond and soil temperature retention.

These temperatures readings in fig 4.7 above indicated that the level of evaporation was almost identical in all the Treatments since they varied by almost 1°C with the exception of the month of September. We thus considered the rate of evaporation to have no considerable effect on either of the treatments and our study.

#### 4.2.3.10 Dissolved oxygen

The results on dissolved oxygen were captured in figure 4.8



**Figure 4.8: Graphical presentation of Dissolved Oxygen**

In each of these treatments, there was recorded fluctuations on the levels of dissolved oxygen. The results in treatment I show the dissolved oxygen levels changes from 5.15 mg/L to 4.57 mg/L then to 5.03 mg/L which dropped to 4.53 mg/L and further to 3.75 mg/L. In treatment II, there a dropped from 3.52 mg/L then an increase to 7.2 mg/L and a drop to 6.58 mg/L then to 3.49 mg/L. There was dropped from 5.07 mg/L to 2.89 mg/L of dissolved oxygen levels in treatment III followed by an increase to 7.74 mg/L and a drop to 4.82 mg/Which was followed by a drop to 3.18 mg/L.

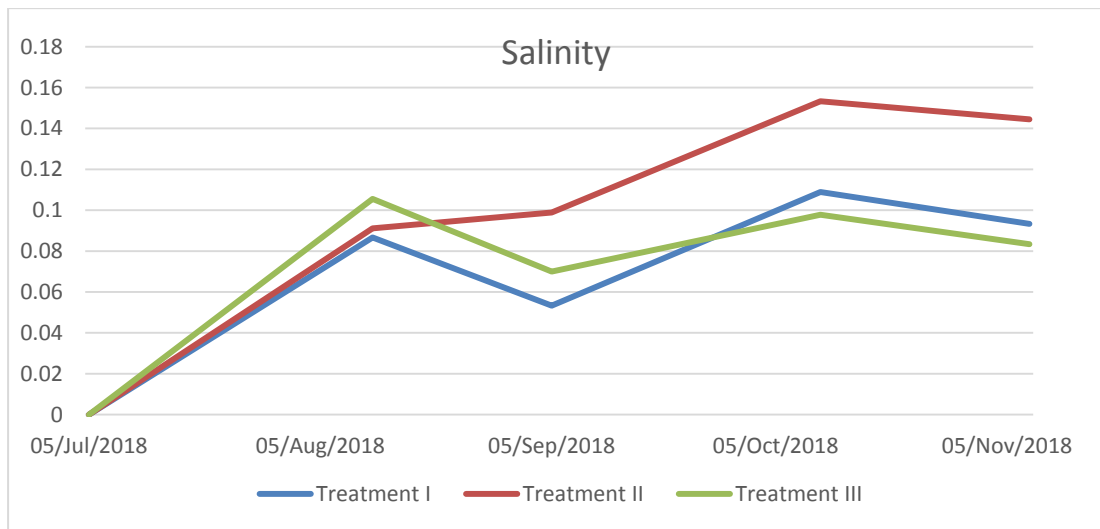
Berg, Berg and Nguyen (2012) observed that in rice growth oxygen is vital during the development of radicals. After maturity the rice is able to photosynthesize and thus able to produce oxygen during the day. The Nile tilapia on the other hand requires dissolved oxygen at near-saturation or saturation level (3mg/L). The dissolved oxygen (DO) concentration and pH of water in a rice paddy are positively correlated because the DO concentration is largely a result of photosynthetic activity, which consumes carbon dioxide and reduces dissolved CO<sub>2</sub> (and thus H<sup>+</sup> concentration), raising both pH and dissolved oxygen levels. Both, on the other hand, are reduced when respiration is the primary mode of action as was observed in the results acquired for both dissolved oxygen and pH. The oxygen levels on all treatments were observed to be above 3mg/L during the period of study and actually increasing from 4.57mg/L to 5.03mg/L in Treatment I, 3.52mg/L to 7.22 mg/L in Treatment II and 2.89mg/L to 7.74mg/L in Treatment III

The dissolved oxygen decreased rapidly in treatments I and III while there was gradually decrease in Treatment II. This was probably due to the use of Nitrogen fertilizers used in the 2 treatments. The fertilizers utilized sparked the growth of algae, aquatic weeds, and phytoplankton, all of which contribute to a reduction in DO levels in the water. Plants and weeds produce more oxygen as they grow, resulting in a rise in the amount of oxygen dissolved until the rice grew in September, when the amount of oxygen dissolved began to decrease. The amount of light that reaches the water determines how much oxygen is produced during photosynthesis as the plant canopy increased over time as the rice grew. In Treatment II there was no fertilizer thus minimal to no aquatic plants present. This lead to the stable conditions observed throughout the period of study.

#### **4.2.3.11 Salinity of the water (mg/l)**

Salinity, which is the amount of salt dissolved in a body of water was analyzed and recorded .

The analysis on status of salinity was captured in figure 4.9.



**Figure 4.9: Graphical presentation of Salinity (mg/l)**

In treatment I, the started at 0.09, dropped to 0.05, increased to 0.11 and then dropped to 0.09. the salinity in treatment II was first recorded at 0.09 then increased to 0.10 climbing up to 0.15 and lastly dropped to 0.14. Although the salinity in Treatment III was first recorded at 0.11, it decreasing to 0.07 before dropping to 0.10 and further decreasing to 0.08.

Salinity is defined by Fermon (2011) as a measurement of total dissolved salts in a water body. Salinity refers to the amount of water-soluble salts that are necessary for phytoplankton growth. As per Azevedo (2015), Nile tilapia can be raised in water salinities as high as 7 g L<sup>-1</sup> without harming the parameters. Treatment II experienced higher levels of salinity due to the feeds used which were rich in calcium (Ca<sup>2+</sup>) and magnesium (Mg<sup>2+</sup>) . In treatments, III and I the results were almost identical through the period of study indicating that feeds affected the salinity of the pond. The salinity pattern in treatments II and I seem to follow the temperature regime due to evaporation and rain patterns and were within the ranges acceptable for fish farming apart from 12/08/2018 in treatment III 0.11g/L and 11/10/2018 in Treatment I 0.11g/L, which were minimal.

### **4.3 Hypothesis testing on physical chemical quality of water**

The study tests the hypotheses using one-way Anova (one way analysis of variance)

**Table 4.7: Comparison of physical-chemical parameters between the treatments**

	Phosphate	Nitrate	Nitrite	Ammonia	Phosphorus	Nitrogen
Treatment	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean±SE
Treatment 1	0.08±0.02	0.10±0.03	0.05±0.01	0.41±0.09	0.022±0.007	0.23±0.03
Treatment 2	0.09±0.01	<LoD	0.04±0.00	0.34±0.04	0.041±0.011	0.22±0.02
Treatment 3	0.07±0.01	0.43±0.02	0.04±0.00	0.32±0.08	0.016±0.004	0.24±0.04
p-value	0.647	<0.001	0.122	0.599	0.080	0.836

Phosphorus is useful for providing energy to growing plants and lack of phosphorus leads to stunted growth of plants. So, it was important for the growth of rice in this experiment. The levels of phosphates were 0.08±0.02 mg/L in treatment 1, 0.09±0.01 mg/L in treatment 2 and 0.07±0.01 mg/L in treatment 3.

These levels were found not to differ statistically across the treatments ( $p = 0.647, \alpha = 0.05$ , One-way ANOVA). Disturbing the soil, on the other hand, promotes soil porosity by promoting phosphate transfer to the soil (Halwart & Gupta, 2004). According to these findings, introducing fish into the water did not have a substantial impact on the phosphorus cycle.. Thus, the findings in this study disagreed to those found by to Halwart and Gupta (2004).

Nitrate levels varied significantly between the treatments ( $p < 0.001, \alpha = 0.05$ , independent t-test). The levels of Nitrate in treatment II were below the detection limit of the instrument however the levels of Nitrate in treatment was 0.43±0.02mg/L as compared to treatment 1 that had 0.10±0.03mg/L.

The levels of Ammonia show a significant difference across the treatment groups ( $p > 0.05, \alpha = 0.05$ , One-way ANOVA). The results show that at  $\alpha = 0.05$ , ammonia is related to nitrites and nitrates as well as pH. Notably, Halwart and Gupta (Eds) (2004) posit that The concentrations of ammonia (NH<sub>3</sub>) and ammonium (ionized form, NH<sub>4</sub><sup>+</sup>) are proportional to the pH of the water, with NH<sub>3</sub> concentrations increasing by a factor of ten for every unit increase in pH from pH 7 to 9. (Roger 1996) When NH<sub>4</sub><sup>+</sup> combines with water, the number of nitrites and nitrates produced increases.

The levels of Nitrogen did not show a significant difference across the treatment groups ( $p > 0.05, \alpha = 0.05$ , One-way ANOVA).

**Table 4.8: Comparison physical-chemical parameter between the treatments**

Treatments	pH	EC	TDS
	Mean±SE	Mean±SE	Mean±SE
Treatment 1	7.14±0.19	171.77±9.23 <sup>a</sup>	101.12±6.69 <sup>a</sup>
Treatment 2	7.47±0.18	250.79±17.70 <sup>b</sup>	153.33±12.36 <sup>b</sup>
Treatment 3	7.17±0.18	174.41±8.01 <sup>a</sup>	107.28±5.78 <sup>a</sup>
p-value	0.361	<0.001	<0.001

Conductivity levels varied significantly between the 3 groups ( $p < 0.001, \alpha = 0.05$ , One-way ANOVA) with further analysis showing a significantly higher electrical conductivity in treatment group II ( $250.79 \pm 17.70 \mu\text{S}/\text{cm}$ ) as compared to the other treatment groups.

Total dissolved solids varied significantly across the groups ( $p < 0.001, \alpha = 0.05$ , One-way ANOVA) with further analysis showing higher TDS in treatment group 2 ( $153.33 \pm 12.36 \text{mg}/\text{L}$ ) as compared to the other treatment groups.

The research assesses the capacity of water to conduct electricity to determine the quantity of ions or salts in it. Water with a high conductivity has a good buffering capacity in general. This is measured in Siemens (S) per centimeter at 25°C and fluctuates with temperature. If the electrical conductivity of the water is between 100 and 300 S/cm at 25°C, it is considered ideal for Nile Tilapia cultivation. In our three treatments we observed that the electrical conductivity for all the treatments was between those ranges with the exception of Treatment II on the 11/10/2018 and 08/11/2018.

**Table 4.9: Comparison physical-chemical parameter between the treatments**

Treatments	Temp(°C)	DO	Salinity
	(Mean±SE)	(Mean±SE)	(Mean±SE)
Treatment 1	23.44±0.50	4.42±0.19	0.07±0.01
Treatment 2	23.88±0.55	5.30±0.58	0.10±0.02
Treatment 3	24.03±0.60	5.06±0.53	0.20±0.13
p-value	0.729	0.391	0.425

*Mean±SE followed by the same small letter within the same column do not differ significantly from one another (SNK-test,  $\alpha = 0.05$ )*

The temperature levels showed a narrow range of variation between the different treatment groups, with the highest ( $24.03 \pm 0.60^\circ\text{C}$ ) mean temperature recorded in

treatment group 2 and the lowest ( $23.88 \pm 0.55^{\circ}\text{C}$ ) in treatment group 2. The temperature reported between the groups, however, did not differ significantly ( $p = 0.729, = 0.05$ ).

Although the quantities of dissolved oxygen varied slightly, the differences were not statistically significant ( $p > 0.05$ ).

Although the quantities of dissolved oxygen varied slightly, the differences were not statistically significant ( $p > 0.05$ , One-way ANOVA).

Thus, Table 4.11 shows the results of a one-way ANOVA test on fish development.

**Table 4.10: Growth of fish hypothesis testing results**

Time of sampling	Treatments			
	Treatment 1		Treatment 2	
	Length(cm)	Weight (gms)	Length(cm)	Weight(gms)
<b>Jul-18</b>	$8.60 \pm 0.17^b$	$14.4 \pm 0.84^a$	$8.6 \pm 0.17^a$	$14.4 \pm 0.84^a$
<b>Sep-18</b>	$9.84 \pm 0.20^b$	$19.35 \pm 0.60^a$	$10.2 \pm 0.18^a$	$26.5 \pm 0.95^b$
<b>Oct-18</b>	$11.7 \pm 0.37^b$	$34.0 \pm 0.69^b$	$12.8 \pm 0.25^b$	$46 \pm 1.31^c$
<b>Nov-18</b>	$12.2 \pm 0.18^b$	$44.2 \pm 0.61^b$	$16.4 \pm 0.15^d$	$65 \pm 1.52^d$
<b>P-value</b>	$< 0.001$	$< 0.001$	$< 0.001$	$< 0.001$

Within the same column, mean values for fish weight followed by the same small letter do not differ significantly (SNK-test,  $= 0.05$ ). Within the same column, mean values for fish weight followed by the same small letter do not differ significantly (SNK-test,  $= 0.05$ ).

## **CHAPTER FIVE**

### **SUMMARY, CONCLUSIONS AND RECOMMENDATIONS**

#### **5.1 Introduction**

Prominently, the present chapter includes an overview of research results, research conclusions, and survey recommendations (policy and additional research).

#### **5.2 Summary of Findings**

This part outlines the findings of the study, and the summary is in keeping with the study's goal to; determine the level of yield of rice in fish integrated treatments, determine the growth of fish in both treatments, determine the physico- chemical characteristics in the three treatments.

##### **5.2.1 Rice yield in fish integrated treatments**

The study found that presence of fish in the rice field automatically rules out the use of chemical pesticides. This was shown by the higher rice yield in treatment II than treatment III. Treatment II had fish and rice without use of chemical pesticides while treatment III had rice alone but with chemical pesticides. In this study, it was demonstrated that rice and fish can be harvested from the same field with minimal additional expenditure. Regardless of application of fertilizer or not, the rice will have high yields. However, application of urea increases the ammonia concentration and additional fertilizer was necessary for supporting phytoplankton production. It was proved in this research that rice and fish may be harvested from the same area with little additional cost. That is using fish fingerlings and feeds increases the net returns, while also providing an affordable source of protein to the farmers.

When fish is integrated into rice paddies, the fish feed on the phytoplankton and zooplankton present in the irrigated water. The fish's size and weight rise as a result of additional artificial feed feeding. The size of the fish at stocking, the culture period in the rice fields, and the amount and quality of supplementary feed all influence the fish's growth. The survival rate of fish in culture systems I and II is 83 percent and 90 percent, respectively, demonstrating effective management and adaptability of Nile tilapia for rice integration systems.

The net returns from fish harvest are higher where fish is integrated into rice paddies than where the fish are not stocked in rice paddies. This is attributed to culture of fish which results in higher net returns.

### **5.2.2 Growth of fish in Rice Paddies**

When fish is integrated into rice paddies, they feed on the phytoplankton and zooplankton present in the irrigation water. The fish's size and weight rise as a result of additional artificial feed feeding. The size of the fish at stocking, the culture period in the rice fields, and the amount and quality of supplementary feed all influence the fish's growth. Notably, the survival rate of fish is 83% and 90% for culture systems I and II respectively, indicating good management and suitability of Nile tilapia for rice integration system.

The net returns from fish harvest are higher where fish is integrated into rice paddies than where the fish are not stocked in rice paddies. This is attributed to culture of fish which results in higher net returns.

### **5.2.3 Physico- chemical quality of the water in integrated rice-fish farming**

Presence of rice in paddies reduces the levels of Nitrates in the water because the rice roots contribute nitrogen through fixation symbiotic relationship with rhizobia bacteria. The rhizobia bacteria break down Nitrogen compounds to produce Nitrates which are assimilated by the plants and more specifically the rice, helping the rice to grow and absorb more of Nitrates concentration. Since the rice and other plants (such as weeds) are using the nitrates, then the level of nitrates concentration reduces drastically. The Nitrates continually decreased as the rice grows thereby demanding more Nitrates hence the reduction of the Nitrates.

Integrating fish fingerlings in rice paddies would initially not affect the Nitrates concentration but Nitrates decrease as rice uses the available nitrates in the water. Notably, the study found that the fish feed on organisms in the ponds. The maturing fish increases the nitrates in the water as the fish grow. This is so because since the fish fingerlings are still maturing, they produce low ammonia excreted. When the fingerlings are matured (fingerling takes about three months to mature) they would

therefore produce more ammonia excrete, which causes abrupt increase of nitrates in the water.

Integrating fish into rice paddies increased the amount of Nitrogen because the water is receiving increased excrete from the Nile Tilapia, which is rich in Nitrogen compounds leading to accumulation of Nitrates. The soil contains denitrifying bacteria which convert Nitrogen compounds into Nitrogen, hence increased level of Nitrogen. As previously stated, nitrate levels rose dramatically, resulting in nitrate buildup in the soil. These nitrates are subsequently reduced by facultative anaerobic bacteria, resulting in the creation of oxygen for use in plant root respiration, as well as the emission of nitrogen as a by-product, resulting in an increase in nitrogen levels..

The study found that fish in rice paddies controls the organisms in the water as they feed on them and hence reducing them. So, absence of fish to feed on organisms in the ponds, exposes the rice to attacks by these pests organisms. In which case, the rice is attacked by the organism, leading to their death. The dead rice and weed plants decompose producing Nitrogen and Carbon dioxide. The remaining rice plants take all of the nitrates, lowering their levels. As a result, fish in rice paddies have an impact on the nitrogen cycle in rice fields, as they produce and capture more nitrogen than typical rice paddies. Fish may assist save nitrogen by reducing photosynthetic activity (by grazing on photosynthetic aquatic biomass and increasing turbidity), lowering pH and reducing ammonia volatilization, according to the research.

The study found that when the fingerlings are still maturing, the plants consume the available ammonia as was the case with Nitrates. Due to nitrogen fixing bacteria present, the level of ammonia decreased. The Nitrifying bacteria convert the Ammonia into Nitrogen and maintain the Ammonia concentration levels below 0.5mg/L. The ammonia is low throughout due to the presence of nitrogen fixing bacteria which are fertilized.

The study found that the salinity increased slightly during the experiment. The Nile tilapia do well in waters with salinity of between 0.05g/L to 0.1g/L. Presence of feeds (rich in calcium ( $\text{Ca}^{2+}$ ) and magnesium ( $\text{Mg}^{2+}$ ) highly increases the salinity; with feeds affecting the salinity of the paddies. The salinity pattern was found to follow the temperature regime due to evaporation and rain patterns and was within the ranges acceptable for fish farming.

The study established that fish also affects the phosphorus cycle. The fish increase soil permeability and facilitate phosphate transfer to the soil by disrupting the soil. Phosphorus, in particular, is frequently a limiting nutrient for primary production since it is typically fixed in the soil and inaccessible to plants in the rice paddy.

It was found that the pH of the waters in the paddies was between the optimum limits for Nile Tilapia (that is between 6.5 and 8.5). However, there are fluctuations (increases and decreases at various times) due to fluctuation in the amount of dissolved oxygen which has a positive correlation with pH. The introduction of urea fertilizer during the early stages of rice growing increased the alkalinity of the water and gradually decreased as the rice grew.

It was established that the electrical conductivity, regardless of whether there is fish in the paddies or not, was within the recommended ranges. The introduction of fish does not have any significant effect on the EC. Likewise, the Total dissolved solids were not affected by introduction of fish into the rice paddies. It should however be noted that electrical conductivity is directly related to the Total dissolved solids. TDS is normally controlled by the source of pond water and nearby land use. The TDS affects the electrical conductivity as increase in TDS led to an increase in Conductivity and vice versa

The study established that temperature conditions fluctuate evenly in paddies with fish and those without fish ; because temperature across the treatment is attributed to the geographical location of the pond and soil temperature retention. The diurnal changes, on the other hand, are frequently about 4°C and decrease as the rice canopy concentration increase..

The oxygen levels on all treatments were observed to be above 3mg/L during the period of study and actually increasing from 4.57mg/L to 5.03mg/L in Treatment I, 3.52mg/L to 7.22 mg/L in Treatment II and 2.89mg/L to 7.74mg/L in Treatment III

In integrated fish rice farming, the dissolved oxygen is in stable conditions. The DO decreases gradually where fertilizer is introduced in treatments because it promotes the growth of algae, aquatic weeds all of which contribute to a decrease in the amount of DO in the water.

### 5.3 Conclusions

Rice yields increased by including fish into rice production. The yields from these rice fields were marginally higher than those from rice paddies that did not have fish. As a result, using fish instead of insecticides in rice fields is cost-effective. Indeed, introducing fish into rice fields removes the need for pesticides. Thus, integrating fish into rice paddies leads to high rice yields, and creates a more sustainable agro-ecosystem. This approach increases rice and fish harvest from the same field at minimal additional expenditure and with increased net returns while also providing an affordable source of protein to the farmers. As it leads to high rice yields, it also creates a more sustainable agro-ecosystem. It was revealed that integrated fish- rice farming ensures water use efficiency maximization and contributes to drastically reducing chemical pesticides utilization.

Further, integrated rice-fish farming increase fish yield as it also increases the farmers' income. It provides for additional income from fish yield in the land where rice is harvested, delivering a wide range of economic benefits.

The study concludes that that integrated fish- rice farming has ecological effects. Soil productivity is improved and diversified, as well as soil protection, higher nutrient uptake, and biological pest management as well as drastically reducing chemical pesticides utilization. The fish in rice paddies control on the volume of organisms in the water since the fish feed on these organisms. Integrating fish into rice allows the fish to feed on these pests, drastically reducing chemical pesticides utilization. Thus, it results into sustainable environment, increased economic income and diversified food varieties

Integrated rice-fish farming significantly improves some water quality parameters of physical- chemical quality of water. Notably, rice paddies significantly reduces the levels of Nitrates in the water because the rice roots contribute Nitrogen fixation since they have symbiotic (rhizobia bacteria) relationship with bacteria. Meanwhile stocking fish in rice paddies significantly increases the Nitrates in the water and the rice uses these Nitrates in the water causing a drastic decrease in the Nitrates. The study revealed that fish feed on organisms in the paddies. Mature fish fingerlings produce more Ammonia excrete, which causes abrupt increase of Nitrates in the water. The study revealed that integrating fish into rice paddies increases the amount of Nitrogen because

the water receives increased excrete from the fish, which is rich in Nitrogen compounds leading to accumulation of Nitrates. Fish in rice paddies consume on photosynthetic aquatic biomass, raising turbidity, keeping pH low, and lowering ammonia volatilization. The Ammonia concentration levels are maintained at below 0.5mg/ due to presence of Nitrogen fixing bacteria which are fertilized. The presence of feeds  $C^{a2+}$  and  $Mg^{2+}$  highly increases the salinity of the paddies. Notably the salinity pattern follows the temperature regime due to evaporation and rain patterns. The temperatures were within the ranges acceptable for fish farming. The study concludes that integrating fish in rice paddies increases the phosphorus cycle. The fish increase soil permeability and facilitate phosphate transfer to the soil by disrupting the soil. The usage of urea fertilizer during the early stages of rice cultivation increased the water's alkalinity, which subsequently decreased as the rice developed. According to the study, integrated rice–fish farming has social, economic, and environmental benefits. Soil productivity is improved and diversified, as well as soil protection, higher nutrient uptake, biological pest management, and a substantial reduction in the use of chemical pesticides. It also has a health benefit in that the water in the paddies is kept flowing continuously.

## **5.4 Recommendations**

### **5.4.1 Recommendations for Further Study**

At Kenya's Mwea Irrigation Scheme, research indicates that incorporating Nile tilapia fish into rice farming boosts rice production. However, the Mwea Irrigation Scheme represents a small portion of Kenya's total rice production area, and most other rice-producing areas are subject to a variety of meteorological issues that may influence the fish. This confines the applicability of the result to Mwea Irrigation Scheme, limiting generalization of the findings.

The study recommends other scholars to;

1. Conduct further study of rice-fish culture in other rice growing areas of the country
2. o add to the literature and validate these findings, assess the economic and ecological sustainability of incorporating Nile tilapia fish into rice production in additional rice-producing locations in Kenya
3. Assess viability of using other fish species e.g cat fish in Mwea irrigation scheme.

### **5.4.2 Policy Recommendations**

Integrated fish-rice farming was found to have economic and ecological benefits and numerous ecological effects; by ensuring increased economic benefits, food security, biological pest control, sustainable environment and drastically reducing chemical pesticides utilisation. Accordingly, the study makes various recommendations for proliferation of integrated rice fish farming and hence reduce the extensive use pesticides leading to conservation of the ecosystem in Mwea, Kirinyaga, Kenya. the study suggests;

1. There is need for the National and County Government to propagate integrating fish in rice farming. The farmers should integrate fish in rice farming practice, where they will either sell the fish as they do with and other times used the fish for food as nutrition for their bodies
2. Rice farmers in Mwea, Kirinyaga, Kenya should ensure that through practicing integrated fish-rice farming, there is diversified productivity of and protection the soil. This should be enhanced by use of fish to reduce the chemical pesticides through integrated fish-rice farming in order to improve the environment.
3. The study suggests that famers should intensify the use of the technique pf integrated fish-rice farming, which will ensure that the water in their rice fields is not contaminated and has increased nutrients. This ensures avoiding soil pollution as well provide a healthy environment.

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## APPENDICES

### Appendix I: Work Plan

The project will be undertaken between July 2017 and November 2017. The entire schedule for the project will be as follows: -

<b>ACTIVITY</b>	<b>MAY 2017</b>	<b>JUNE 2017</b>	<b>JULY 2018 – DEC 2018</b>	<b>JAN- MAY 2018</b>	<b>NOV. 2019</b>	<b>DEC. 2019</b>
Produce Proposal						
Submission of Proposal Defense						
Tools Development and Data collection						
Data Processing and analysis						
Report Writing						
Final Defense						
Correction and final Submission						

Source (Researcher, 2016)

## Appendix II: Rice seedlings at the nursery



## Appendix III: Tilled land and ponds formed with dykes



**Appendix IV: Researcher taking weight and length measurements of fish fingerings**



**Appendix V: Packaging of fish fingerings**



**Appendix VI: Introduction of fish fingerings into the ponds with rice seedlings**



**Appendix VII: Rice fields without fish and with fish**

