GROWTH PERFORMANCE AND ECONOMIC BENEFIT OF NILE TILAPIA (*Oreochromis niloticus*)AND CHINESE CABBAGE (*Brassica rapachinensis*)IN AQUACULTURE INTEGRATION

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ABSTRACT

A study carried out to evaluate the growth performance and economic benefit of Nile tilapia and Chinese cabbage under integration system. Nine ponds and twelve vegetable plots were used. Three ponds treated with feed only (T_1), another three ponds with chicken manure only (T_2) and the last three ponds with chicken manure and supplementary feed (T_3). Fish with an average weight of 1.2 g were stocked at rate of 5 fingrlings/m^2 in each pond. Fish were fed at 5% of their body weight and the ponds were fertilized at rate of 30 kg/pond at interval of two weeks. Three plots irrigated with water from (T_1), another three plots with water from (T_2) and last three plots with water from (T_3). Control plots irrigated with water from stream. Growth performance of fish was monitored by measuring fish body weight and Chinese cabbage by measuring diameter, length of leaves and counting the number of leaves. Cost benefit analysis was conducted at the end of experiment using data of revenue, fixed cost and variable cost. The experiment lasted for 6 months. Growth performance of fish and Chinese cabbage were analyzed using analysis of variance (ANOVA). Results showed that there was significant difference (ANOVA, $p<0.05$) on growth performance of Nile tilapia among the treatments. Ponds received manure and supplementary feed had twice as much yield compared to ponds received feed and manure only. Vegetable plots irrigated from fish ponds had significantly higher leave diameter, length, number of leaves and yield compared to those irrigated with stream water ($p<0.05$). Economic benefit analysis showed higher net profit for ponds received manure with supplementary feed while ponds with manure only contribute to higher benefit cost ratio. This study confirms the contribution of integrated agro-aquaculture in farm productivity and income.

DECLARATION

I, Mlelwa Tito,do herebydeclare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submittedin any other institution.

Mlelwa Tito Date

(MSc. MNRSA Candidate)

The above declaration is confirmed by;

Dr. Lamtane, H.A. Date

(Supervisor)

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DEDICATION

This research work is dedicated to my Lord, the Saviour, and Jesus Christ. In the potter's hands, He makes something out of nothing. Thanks Father, for your faithfulness, grace and mercy. To God be the glory. Alsothis research dissertation is dedicated to all scientists in my country and over the world; are the ones who fight against development in Tanzania.

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LIST OF ABBREVIATIONS AND SYMBOLS

ANOVA	Analysis of variance
BCR	Benefit cost ratio
CF	Crude fiber
Cm	Centimeter
CP	Crude protein
df	Degree of freedom
DM	Dry matter
DO	Dissolved oxygen
DWG	Daily weight gain
EE	Ether extract
et al	and others
FBW	Final body weight
FCR	Feed conversion ratio
G	Gram
INBW	Initial body weight
Kg	Kilogram
L	Liter
M	Meter
m^2	Meter squared
pH	Acidity or alkalinity of water
PI	Profit index
Se	Standard error
SEM	Standard Error of the mean
SR	Survival rate

SRG	Specific growth rate
SUA	Sokoine University of Agriculture
TC	Total cost
Temp	Temperature
TR	Total revenue
TSh	Tanzania Shilling
TVC	Total variable cost
WG	Weight gain
%	Percentage

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Integrated fish farming is a simultaneous culture of fish with livestock and/or crops production in one production unit with a linkage and synergy among various products during production. Integrated aquaculture has been practiced in many countries in order to increase fish yield through fertilization of fish pond using different sources of organic fertilizers, such as poultry, cattle and pig manure (Boyd and Tucker, 1998). Poultry manure is widely used in freshwater integrated agro-aquaculture (Nwabueze, 2011).Potential benefits of integrated agro-aquaculture are not only a more even distribution of opportunities to generate cash, but also a more efficient and ecologically sustainable use of scarce resources (Prein, 2002).The integration of fishes with animals and crops holds a considerable potential for augmenting production of animal protein, generation of employment opportunities and improvement of socio-economic conditions of the farmers. It has been proved that integrated livestock-fish-crops are not only technically feasible but also economically viable (Tajuddin, 1980; Mohamad*et al*., 1990).

In addition to increasing total production, income and employment, integrated farming systems enhance ecological sustainability since wastes are recycled, thus reducing their potential for environmental pollution (Jayanthi *et al*., 2003). Outputfrom one subsystem in an integrated farming system which otherwise may have been wasted become an input to another subsystem resulting in a greater efficiency of output of desired product from the land/water in farm (Edward *et al*., 1988).Recycling of wastes products from one product to another optimizes use of resources in production unit resulting on low production costand increase profit in production unit. Integrated fish farming create diversification of products from one production unit to another.

The inclusion of fish farming in integrated system improves utilization of resources like water, farm by-products, land and labor. Pond water for instance does not only serve farmed fish but also irrigate homestead crops and supply water for animals. As a source of irrigation, pond water is richer in nutrients than water from wells and also contains nitrogen-fixing blue green algae, which can improve soil fertility (FAO, 2000). While crops like vegetables can be watered directly from pond water, other crops like banana, sugar cane and yams can benefit from pond moisture.Fish farming technology integrated into the existing farming system has been viewed as an appropriate option for increasing agricultural productivity in Tanzania (Shoko, 2013; Wetengere, 2010).Moreover, phosphorus, nitrogen and potassium are the essential elements needed in the soil for the plant growth. During flushing of pond water into the garden the soil will be rich in those three elements from thepond water fish pond hence increase the crops productivity around the fish ponds.

Integrated agro-aquaculture provides economic increment due to multi-products in the system. The production of poultry, fish and vegetable could contribute significantly to wealth creation in production unit instead of single product.Another economic benefit of integrated agro-aquaculture is the elimination of the cost of the water for vegetable irrigation. Integrated aquaculture reduces production costs of the farm's products (Nobre *et al*., 2009). The aim of on-farm integrated agro-aquaculture is the allocation of resources and the management of by-products to maximize profit from theintegrated production unit. Sub-systems may be linked to utilize end productsand/or by-products and/or waste (Rupasinghe*et al*., 2010).The rate of nitrogen, phosphorus and potassium released, particularly in the most available forms has been used as an indicator of wastes value for fertilization of fish ponds. The question is how best we can use our limited resources to increase production.

Aquaculture production system in East Africa at present is small scale earthen ponds characterized by low inputs and yields (Rutaisire *et al*., 2014). In East Africa studies on integrated agro-aquaculture is limited, however, few studies have been documented(e.g.Shoko *et al*., 2011) compared integrated and non-integrated systems in Lake Victoria basin, Tanzania using Nile tilapia and Kale without looking on the growth performance of vegetables.Dey *et al*.(2010) assessed the social economic impact of integrated agro-aquaculture in Malawi; andKaggwa *et al*. (2006) in Uganda using Lake Victoria ecotone studied the nutrients dynamics in integrated fish and vegetable systems. The present study aimed at assessing the growth performance and economic benefit of integrated Nile tilapia (*Oreochromis niloticus*) and vegetable (*Brassica rapa chinensis*) in chicken, fish and vegetable integration.

1.2 Problem Statement and Justification

Integrated agro-aquaculture plays a significant role in increasing manifold production, income, and nutrition and employment opportunities of rural populations. Integrated farming can make a significant contribution to food security for lower income people as well as to poverty reduction and improvements in livelihoods elsewhere. In southern Malawi integrated agro-aquaculture technology is associatedwith total productivity that is 11% higherfor adopters than non-adopters(Dey*et al*.,2010). There is a positive association between productivity and profitability with the level of integration in a production unit.In recent years the concept of integrating aquaculture into other agricultural systems has received much attentionat rural development communities. Although some fish farmers practice integrated fish farmingto increase productivity little information is available on growth rate of fish (*Oreochromis niloticus*) and vegetable(*Brassica rapa chinensis*) under chicken, fish and vegetable integration.Therefore, the findings from this study provide baseline information on functioning of the system.

1.3 Objectives

1.3.1 Overall objective

To determine growth performance and economic benefit of Nile tilapia (*Oreochromisniloticus*) and Chinese cabbage (*Brassica rapachinensis*)in chicken, fish and vegetables integration.

1.3.2Specific objectives

i. To determinegrowth performance and yieldof Nile tilapia (*Oreochromis niloticus*) in chicken, fish and vegetable integration.

ii. To determine growth performance and yield ofChinese cabbage (*Brassica rapa chinensis*) in chicken, fish and vegetable integration.

iii. To determine economic benefits of integration aquaculture ofNile tilapia and Chinese cabbage system.

1.4Hypothesis

Chicken manure has significant effect on fish and vegetable growth and yields performance.

CHAPTER TWO

2.0LITERATURE REVIEW

2.1Nutritional Importance of fish

Aquaculture plays an important role in nutrition, food security and livelihoods. Fish is an important dietary animal protein source in human nutrition. Recently production of aquatic species through aquaculture for protein supply has been encouraged throughout the world (Abbas *et al*., 2010). According to Subramanian *et al*.(2014) fish is a good substitute of protein for red meat in the diet. Fish contains almost all the essential amino acid and minerals *viz*., iodine, phosphorus, potassium, iron, copper and vitamin A and D in desirable concentrations (Sandhu, 2005).

Aquaculture contributes to world food and itssupplies have been increasing rapidly in recent decades (Zhao*et al*., 2010). Fish provides access to the nutritionally adequate food for the improvement in the quality of diet of a poor person in the society. (Shailender *et al*.,2013). Fish farming has been practiced in East Africa mainly for nutritional needs and to some extent for income generation (Shoko *et al*., 2011). Integrated aquaculture is one of the most feasible solutions to food insecurity and malnutrition in East Africa (Ogello *et al*., 2013).

2.2 The Concept of Integrated Agro-aquaculture

Integrated fish farming is a practice that involves making better and fuller utilization of all the resources held by small farmers (Deomampo, 1998). Integrated agro-aquaculture is the cultivation of aquatic species under controlled with crops or/and livestock during production in relation.The aim of integrated agro-aquaculture is the recycling of animal wastes (feces and urine) to serve as fertilizers and sometimes as food for fish in fish pondsand crops in garden(Olah *et al*., 1986; Knud-Hansen 1998).The introduction of aquaculture into existing agricultural systems through Integrated Agro-aquaculture has been promoted as a sustainable alternative for food production (Cassman *et al*., 2005; IAASTD 2009; Pretty, 2008). The benefits of traditional garden-pond-livestock integrated systems have been widely reported(Luu *et al*., 2002). The integration of aquaculture-agriculture enables the generation of synergies between farm components hence enhanced production. The management of these synergies would reduce the need for external inputs, thus increasing total farm productivity and profitability in an ecologically sound manner through the increase in resource-use efficiency (FAO/IIRR/WorldFish Center, 2001). Integrated agro-aquaculture systems are also promoted as an efficient way to enhance food security (Karapanagiotidis *et al*., 2009; Kawarazuka, 2010; Prein and Ahmed, 2000). Integrated agro-aquaculture systems have been described as more sustainable when compared with other food production systems (Prein, 2007).

Integrated farming systems are usually compared to less diverse and more open systems in terms of nutrients, such as monoculture systems (Gomiero *et al*. 1997; Kautsky *et al*. 1997). It is considered that the diversity of enterprises in integrated agro-aquaculture offers lower risks (Prein et al. 1998; Pullin 1998). Furthermore, the increase of internal recycling and the dependence on external inputs decrease is often considered as more sustainable (Cavalett *et al*., 2006; Dalsgaard *et al*., 1995; Dalsgaard and Oficial, 1997; Pullin *et al*., 2007).

Integrated agro-aquaculture generally involveson-farm waste recycling technique or multiple usages of resources that enhance production capacity, as well asecology improvement (Nimachow*et al*., 2010).The impact of livestock integration with fish increases productivity by manure loading from animals wastes (Zira *et al*., 2015).Maximizing land use, integrated farming approach reduces cost of input, diversifies protein production encourages enterprise combination to improve profitability and therefore farmers socio-economic status (Ayinla,2003).Common approach for increasing fish production in ponds is the direct application of fertilizer, which enhances production of plankton (natural food) in fish pond. The basic principle involved in integrated agro-aquaculture is the harnessing of complementarities of crops, livestock, and fishes, including recycling of farm renewable resources and natural resource conservation (Bhatt *et al*., 2011).Ayinla (2003) reported that, efficiency in resources use is also shared by integrating fish farming with irrigation system.

Different types of integrated fish farming are used in production in order to maximize yield in production unit. Abasi *et al*. (2010) reported thatperformance of fish was higher with fertilization and supplementary feed(2996.53kg/ha/year) while waslower with organic manure (2423.00kg/ha/year). Bhat *et al*. (2011)evaluated the productivity of different animal-fish integrations and reported that cattle-cum-fish had the maximum fish yield (2686.0 kg/ha) and lowest being fromfish-cum-goat (1,867.0 kg/ha). The innovative integrated fish farming is one strategy that can be adopted to increase farm returns per unit area of land (Amarasinghe, 1991).

2.3The Role of Fertilizer in Fish Pond

Different types of organic manure such as poultry, cattle, pig, goat, sheep and duck have been used by fish farmers as the main sources of fertilizer in fish pond. Organic fertilizers have a long tradition in tropical semi-intensive aquaculture when added to ponds; they may ultimately increase fish yields. It stimulates the growth of natural food in fish ponds by providing essential deficient elements, which are utilized by the plankton.The aim of fish pond fertilization is to improve water quality and to increase the variety and quantity of phytoplankton and zooplankton, which eventually leads to high fish yield and economic returns (Abbas *et al*., 2010). Positive effects of fertilization on pond productivity include increasing use efficiency of fertilizers in fish ponds(Thakur*et al.*,2012), increasing the level of primary productivity, (Boyd, 1982; Kangombe *et al*., 2006; Abbas *etal*., 2010), dissolved oxygen, pH and total phosphates (Jana *et al.*, 2001; Afzal *et al*., 2007).

The ecological concept in a fertilized pond is biological production, or the creation of organic matter.Evaluation of fertilization value of different organic manure has been subject of research in aquaculture (Yaro *et al*., 2005). Fish farmers in different countries have increased fish yields in ponds by using organic manure (NAERLS, 2003). It has been reported that one kg of fish can be produced by using about 17 kg of chicken manure (Fang *et al.,* 1986).

2.4Utilization of Fertilized Fish Pond Water in Crop Production

Nutrients can be obtained from various sources such as air, water and soil which can provide several of essential nutrients. Nitrogen, phosphorous and potassium contained in fertilized fish pond becomes fertilizer to agricultural crops. Pond effluents have been applied to crops as irrigation water (Al-Jaloud *et al*., 1993; Hussein and Al-Jaloud, 1995). Plants require essential elements for normal growth and for completion of their life cycle. Those used in the largest amounts are non-mineral elements which are carbon, hydrogen and oxygen. Other elements are taken up by plants only in mineral formfrom the soil.

Plants need relatively large amounts of nitrogen, phosphorus, and potassium.It has been reported that organic farmingincreases the level of total nitrogen, nitrate and available phosphorus in soil and prevent nutrients leaching (Hansen *et al*., 2001).Nitrogen, phosphorus, potassium and water are considered as the major limiting factors in crop growth, development and finally economic yield (Glass, 2003; Parry*et al*., 2005);however, of the three major nutrients, Plants require nitrogen in the largest amounts. Nitrogen promotes rapid growth, increases leaf size and quality, hastens crop maturity, and promotes fruit and seed development on the other hands, normal plant growth cannot be achieved without phosphoruslucky enough water from fertilized fish pond contains such nutrients.

2.5The Economicsand environmental benefits of Integrated Agro-aquaculture

Agro-aquaculture provides rationale for environmental management and multi-products within a production unit. Agro-aquaculture can purify the aquaculture effluent by absorbing nutrients that would otherwise accumulate or be discharged into the environment (Naegel, 1977; Watten and Busch, 1984; Rakocy and Hargreaves, 1993; Adler *et al*., 2000) and resulting in damaging the environments. This reduces waste water effluent costs charged from the aquaculture system, and environmental damage costs. Jagath *et al*. (2010) reported that water requirements of the integrated system are less than the sum of the requirements for the stand-alone systems to the extent that water can be shared between the two systems. It is also important to note thatthe environmental benefits of aquaculture integration might be lost when aquaculture production systems are intensified, as intensive fish production based on external inputs produces higher emissions to soil, water and air than semi-intensive and extensive, integrated fish production (Nhan *et al*., 2006). Integrated agro-aquaculture does provide recycling of wastes in the system which can cause environmental hazards.

Integrated agro-aquacultureenhances on-farm resource-useefficiency and productivity via the integration of resource flowswithin the system. Deny *et al*.(2010) reported that integrated agro-aquaculture farmers had higher overall returns to family labor and thus productivity and higher household incomes.Itprovides products diversification;

employment and income generation in production unit. Integrated agro-aquaculture is better off in terms of outcomes such as productivity, income, and food security (Jahan *et al*., 2013).Prein *et al*. (1999) reported that farmers can sustainably and economic beneficially fit a new aquaculture operationinto an integrated aquaculture approach, with flexible and adaptive technology. According to Nnaji *et al*. (2003) integratedfish farming is more profitable than standalone system of farming. Integrated fish farming provides different sources of income; can be generated from selling eggs, chicken, fish and vegetables or the crops that may becombined in the integrated fish farming. According to Gabriel *et al*. (2007) integrated fish farming provides the farmer with a steady source of income over the year which comes from variousfarm products. Integrated agro-aquaculture is suitable for poor farmers with remarkablylow expenditure pattern in production and continuous low spending forfood and other dietary requirement for home consumption (Ayinla, 2003).Integrated agro-aquaculture is the one of the most viable (resources use maximization), reliable (availability ofproducts) and profitable (selling of different products) of any fish farming enterprise.

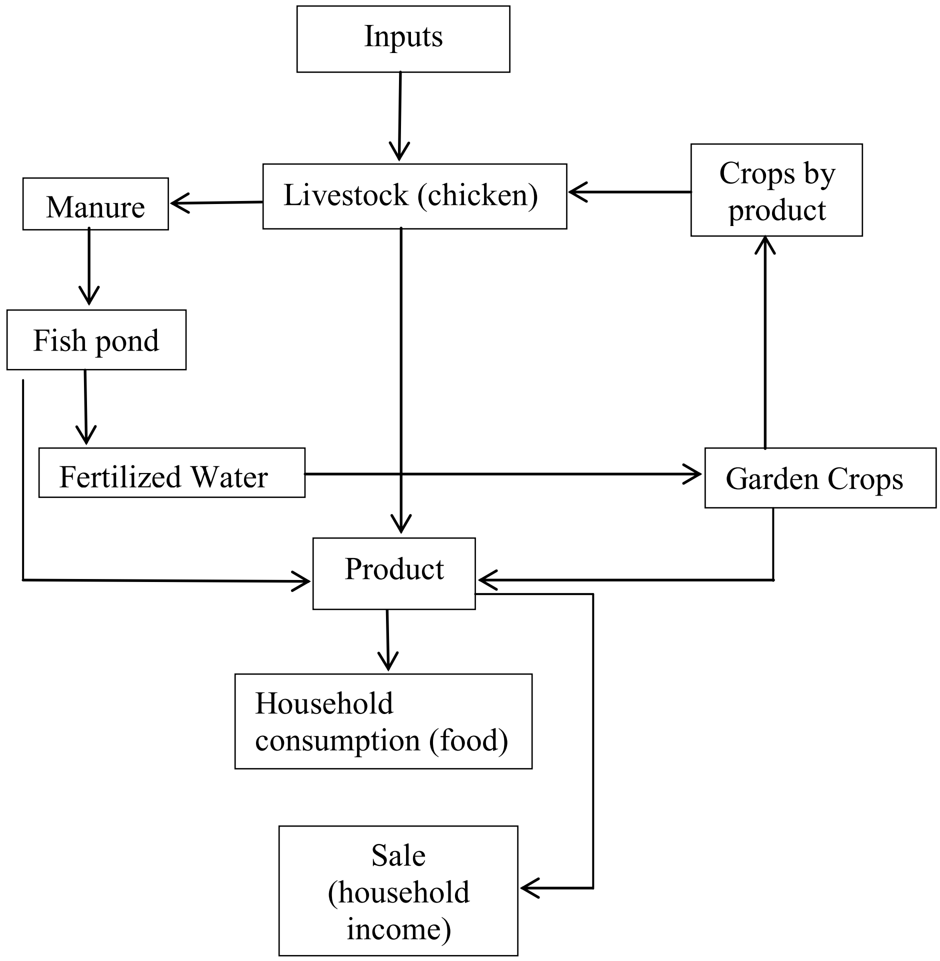

Figure 1: Interaction between various systems in integrated agro-aquaculture

(Source: Tito, 2016)

CHAPTER THREE

3.0MATERIALS AND METHODS

3.1Description of Study Area

The experiment was conducted at Magadu fish farm in the Department of Animal, Aquaculture and Range Science, Sokoine University of Agriculture-Morogoro.The study lasted for six months from January to July.

3.2Experimental Design

This experiment involved three sub systems namely chicken, fish and vegetable subsystem (Fig. 2).

Figure 2:Experimental layout

3.2.1Chicken sub-system

Chicken manure used for pond fertilization was collected from poultry house at the Department of Animal, Aquaculture and Range Science. Before fertilization manure was kept under dry condition. Inevery two weeks a total of 180kg were collected and distributed in six ponds each receiving 30kg.

3.2.2 Fish sub-system

Nine earthen ponds each with a surface area of 300m^2 (15m x 20m) were prepared.Before stocking all ponds were drained completely and exposed to sunlight for one week to dry. The ponds were then refilled with fresh water. All ponds were stocked with Nile tilapia (*Oreochromis niloticus*) at a stocking density of 5 fish per square meter.Three treatments wereinvolved; intreatment one (T_1) three ponds received artificial feeds only, intreatment two (T_2) threeponds were fertilized with poultry manure only and in treatment three (T_3) another threeponds were fertilized with chicken manure and supplementary feed.

3.2.3Preparation of feeds

Supplementary feed was formulated using the following ingredients, maize bran 55%, fish meal 35%, fats7%, and minerals 3%. The ingredients were mixed and dried in sun then grounded into marsh form using milling machine. Fish were fed two times per day at 0900 to 0945hrs and 1700 to 1745hrs.Fish were fed at 5% of total body weight for the first two months then 3% for the remaining period of experiment.

3.2.4Chemical composition of manure and feed

The chemical compositions of the samples were determined through laboratory analysis by using standard methods (AOAC, 1990). Dry matter content was determined by drying the samples to constant weight in oven at 105°C for 18hr. Crude protein was determined using Kjeldahl method. Ether extract was determined by dried sample boiled in ether for 4 hours then the ether is dried the remaining dried matter is called ether extract. Ash was determined by incineration of samples in a muffle furnace at 550°C for 3 hr.

3.2.5 Vegetable sub-system

Twelve vegetable plots each with 12m^2 (6m x 2m) were prepared and planted with seedlings of Chinese cabbage (*Brassica rapa chinensis*). The seedlings were planted at a spacing of 25 cm within a row and 20 cm between the seedlings at each plot. Water from each treatment in fish sub-system was used for irrigation in nine vegetable plots. Water from treatment one was used to irrigate three vegetable plots and the same applied to treatment two and three. The other three vegetable plots were irrigated by stream water acted as control. All vegetable plots were irrigated twice per day between 0700-0900hrs and 1700-1900hrs at a rate of 60litres/plot at once. The experiment was conducted for 45 days.

3.2.6Chemical composition of fish and vegetable

Fish and vegetables were subjected to proximate analysis. The chemical compositions of the samples were determined through laboratory analysis by using standard methods (AOAC, 1990). Dry matter content was determined by drying the samples to constant weight in oven at 105°C for 18hr. Crude protein was determined using Kjeldahl method. Ether extract was determined by dried sample boiled in ether for 4 hours then the ether is dried the remaining dried matter is called ether extract. Ash was determined by incineration of samples in a muffle furnace at 550°C for 3 hr.

3.2.7Water quality monitoring in fish ponds

Temperature, pH, dissolved oxygen and transparency were monitored throughout the experimental period.These parameters weremeasured twice per day in the morning (0700 to 0900hrs) and in the evening (1700 to 1900hrs).Temperature and dissolved oxygen measurements were measured using YSI oxygen meter (model 55, YSI industries-USA) while pH were measured using test strips (JBL Easy Test). Water transparency was measured by using a locally made 100 cm Secchi disk.

3.3Data Collection and Processing

3.3.1Fish growth performance and yield

Body weight of fish was measuredmonthly using electronic weighing balance. Fish were collected using seine net and 5% of totalfish stocked were sampled and measured. The following growth performance indicators weredetermined:

3.3.1.1 Body weight gain (BWG)

i. Mean weight gain $(\text{MWG, g}) = \text{Wf} - \text{Wi}$ ....(1)

Where; W_i = initial mean weight, W_f = final mean weight.

ii. Daily weight gain $(\text{DWG, g day}^{-1}) = \dfrac{\text{Wf} - \text{Wi}}{\text{Time (days)}}$ ....(2)

3.3.1.2 Specific growth rate (SGR)

iii. Specific growth rate $(\text{SGR \%}) = \left(\dfrac{\text{lnWf} - \text{lnWi}}{\text{Time (days)}}\right) x\,100$.............................(3)

Where;

W_f– Fish mean weight at the end

W_i–Fish mean weight at the start

ln-Natural log

t_1-t_0(days) – Running time

3.3.1.3 Fish survival rate

iv. Percent survival rate $(\text{PSR, \%}) = \left(\dfrac{\text{Fh}}{\text{Fi}}\right) \text{x}\,100$ ....(4)

Where;

Fh–Final fish harvested

Fi–Initial fish stocked

3.3.1.4 Apparent Feed Conversion Ratio (AFCR)

This was calculated from the relationship of feed intake and wet weight gain.

v. Apparent feed conversion ratio

$$AFCR = \left(\frac{\text{Total feed consumed by fish (g)}}{\text{Weight gain by fish (g)}} \right) \ldots (5)$$

3.3.1.5 Fish yield

Fish yield was calculated as difference between total fish weight harvesting (kg) and total fish weight stocked per treatment.

vi. $$\text{Net fish yield} = \text{Total fish harvested}(g) - \text{Tota fish stoked}(g) \ldots\ldots..(6)$$

3.3.2 Plankton

3.3.2.1 Plankton identification

Zooplankton and phytoplankton was identified by using picture guide produced by Yamaguchi and Bell (2007).

3.3.2.2Plankton abundance

Water samples were collected using a bucket with a capacity of 20litres in each pond.Plankton net with 35μm mesh size was used to filter water samples and then preserved using 4% formalin. Preserved samples were taken to laboratory for plankton identification and counting. Plankton was counted by using sedge wick rafter counting chamber. Plankton identification and counting was done under compound microscope at 40x magnification. The entire sample was scanned and all observed individuals were recorded and counted.

Phytoplankton numerical abundance was calculated by using a formula given by Greenberg*et al*. (1992).

vii. $$\text{Abundance} = \frac{C \times At \times v}{Af \times F \times V \times Vi} \text{..........................(7)}$$

Where; C=no of organism counted, At =total area of bottom of settling chamber (mm^2), v=volume of concentrated sample (125ml), Af=area of field counted (mm^2), F=no of field counted, V=volume of sample observed (1ml), Vi=volume of sediment sample.

3.3.3Vegetable growth performance and yield

3.3.3.1 Growth performance

Number of leaves, diameter (cm) and length (cm) of Chinese cabbage were determined in each treatment at seven daysinterval throughout the experimental period. The measurements wereconducted starting one week after transplanting. Leaves of Chinese cabbage were counted at each plant and plot. The diameter and length of leaveswere measured using a ruler in each plant and plot.

3.3.3.2 Vegetable yield

Vegetable harvesting began fourteen days after transplanting by removing the lowest leaves of plant at every seven days. Harvested fresh leaves were weighed using spring weighing balance from each of the plots receiving different treatments and summed over the harvested period. At the end of the experiment, all vegetables at the area of 12 m^2 of each plot were harvested and total yield was determined in each vegetable plots and average yield per treatment was calculated including the yield from periodic harvesting.

3.3.4Economic benefits of the system

The economic benefit offish and vegetable integration was determined by calculating the difference of total variable cost and total revenue generated from thesystem. Total return or profit of the system was calculated by summation of profit from the two subsystems. Total variable cost included hired labor, fingerlings purchase, manure, feeds and vegetable seeds. The economic variables determined included net return or profit and benefit cost ratio (BCR).

3.3.4.1 Benefit or profit

Total Revenue given by Price per unit x Quantity (Kg)

$$TR = P \times Q \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Total Variable cost given by Price of unit (Input) x Quantity (Input)

$$TVC = Px \times Qx \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

Profit = Total revenue – (Total Variable Cost + Total Fixed cost)

$$\text{Total Return} = \pi 1 - \pi 2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(10)$$

Where; $\pi 1$Total profit for Fish

$\pi 2$Total profit for Vegetable

3.3.4.2 Benefit-Cost Ratio

The Benefit-Cost Ratio (BCR) is the ratio of the present value of benefits to the present value of costs. It can be expressed as follows:

$$BCR = \frac{\text{Benefit}}{\text{Cost}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(11)$$

3.4StatisticalAnalysis

Data obtained from this study was subjected to one-way analysis of variance (ANOVA) followed by the LSD multiple comparison test for the means at a significance level of $P<0.05$ and presented in ±SE.

The statistical package used for the data analysis was the SPSS for windows version 16.

TheStatistical model for growth and yield performance for fish and vegetable data was:

$Y\text{ij} = \mu + \alpha\text{i} + \ell\text{ij} : \text{i} = 1,2,3,......$

Yij = Dependent variable for fish and vegetable growth performance and yield

μ = Overall mean (constant) observation

α_i = Variation due to treatment on observation

eij= Random error term

CHAMPTER FOUR

4.0 RESULTS

4.1 Chemical Composition of Manure and Feed

Percentage chemical composition of manure and feed used in the present study are shown in Table 1. It shows that there was higher level of ether extract and dry matter in feed compared with chicken manure. On the other hands, results showed higher percentage composition of ash content, crude protein and crude fiber in chicken manure compared with feed.

Table 1: Percentage chemical composition of manure and feed used in this study

Pond input	DM	Ash	CP	CF	EE
Feed	98.54	14.51	24.8	17.48	8.51
Manure	97.32	22.6	37.9	30.21	0.9

4.2 Fish Growth Performance and Yield

Growth performance parameters of Nile tilapia (*Oreochromis noliticus*) reared under integrated system is presented in Table 2 and Fig. 3. Results showed that there was significant difference in growth performance among treatments (ANOVA; F=804.45, P=0.001). Fish in ponds treated with manure and supplementary feed (T_3) showed the highest growth performance compared with those received manure (T_2) and feed alone (T_1).

The results of the post hoc test LSD, showed that there were significant differences in the final body weight (FBW), mean weight gain (MWG) and yield among treatments (Table 1) ($P<0.05$). Treatment (T_3) showed significantly higher daily weight gain (DWG), specific growth rate (SGR), apparent feed conversion ratio (AFCR), body weight gain (BWG) and yield compared to other treatments. However, there was no significant difference on survival rate (SR) among treatments(P>0.05).

Table 2: Growth performance and yield of *Oreochromis niloticus*

Parameter	Treatment		
	Feed (T_1)	**Manure (T_2)**	**Manure+Feed (T_3)**
IBW (g)	1.75±0.12^a	1.91±0.11^a	1.67±0.13^a
FBW (g)	69.10±0.82^a	61.42±0.84^b	116.43±1.37^c
DWG (g)	0.50± 0.01^a	0.48± 0.02^a	0.88± 0.02^b
WG (g)	67.35±10.93^a	59.50±0.85^b	114.76±18.03^c
SGR (%day^{-1})	2.47±0.06^a	2.44±0.07^a	2.79±0.08^b
SR (%)	56.38±2.11^a	53.47±0.37^a	61.20±3.16^a
AFCR	0.17±0.002^a	-	0.19±0.002^b
Yield (Kgha^{-1})	2,328.73±4.61^a	1,961.23±1.23^b	4,264.23±7.04^c

Note: Different alphabetic superscripts in the same row indicate significant difference (P< 0.05).

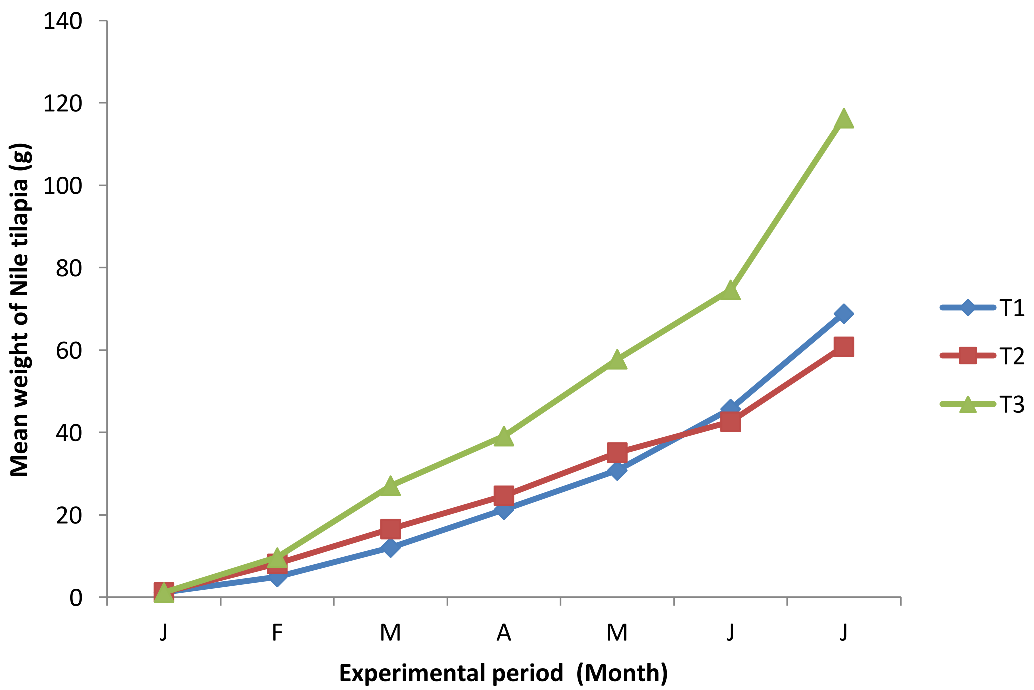

Figure 3: Growth pattern of Nile tilapia (*Oreochromis niloticus*)

4.3 Plankton Abundance

The abundance (cell/litre) of major taxa of phytoplankton and zooplankton species recorded from the three treatments shown in Table 3. Four groups of phytoplankton namely; Chlorophyta, Bacillariophyta, Euglenophyta and Cynophyta and three groups of zooplankton; copepods, cradocerans and rotifers were recorded. Results showed that treatment three (T_3) had significantly higher abundance of phytoplankton and zooplankton compared to treatment one (T_1) and two (T_2) (ANOVA, P<0.05).

Moreover, results showed that Chlorophyta and rotifers were the most dominant groups of phytoplankton and zooplankton respectively in all treatments. Generally treatment three (T_3) had relatively higher abundance of plankton(44%) followed by treatment two (T_2) (34%) and (T_1) (22%, Fig. 4).

Table 3: Plankton abundance in three treatments

Plankton		Treatment		
	Taxa	Feed (T_1)	Manure (T_2)	Feed+manure (T_3)
Phytoplankton	Chlorophyta	$38{\times}10^5{\pm}63{\times}10^{4a}$	$61{\times}10^5{\pm}63{\times}10^{4b}$	$112{\times}10^5{\pm}63{\times}10^{4c}$
	Cyanophyta	$25{\times}10^5{\pm}19{\times}10^{4a}$	$45{\times}10^5{\pm}19{\times}10^{4b}$	$51{\times}10^5{\pm}19{\times}10^{4c}$
	Bacillariophyta	$19{\times}10^5{\pm}17{\times}10^{4a}$	$31{\times}10^5{\pm}17{\times}10^{4b}$	$41{\times}10^5{\pm}17{\times}10^{4c}$
	Euglenophyta	$16{\times}10^5{\pm}21{\times}10^{4a}$	$23{\times}10^5{\pm}21{\times}10^{4a}$	$38{\times}10^5{\pm}21{\times}10^{4b}$
Zooplankton	Copepods	$37{\times}10^4{\pm}3{\times}10^{4a}$	$49{\times}10^4{\pm}3{\times}10^{4b}$	$51{\times}10^4{\pm}3{\times}10^{4b}$
	Cladocerans	$19{\times}10^4{\pm}2{\times}10^{4a}$	$29{\times}10^4{\pm}2{\times}10^{4ba}$	$36{\times}10^4{\pm}2{\times}10^{4b}$
	Rotifers	$48{\times}10^4{\pm}4{\times}10^{4a}$	$79{\times}10^4{\pm}4{\times}10^{4b}$	$81{\times}10^4{\pm}4{\times}10^{4b}$

Note: Different alphabetic superscripts in the same row indicate significant difference (P< 0.05).

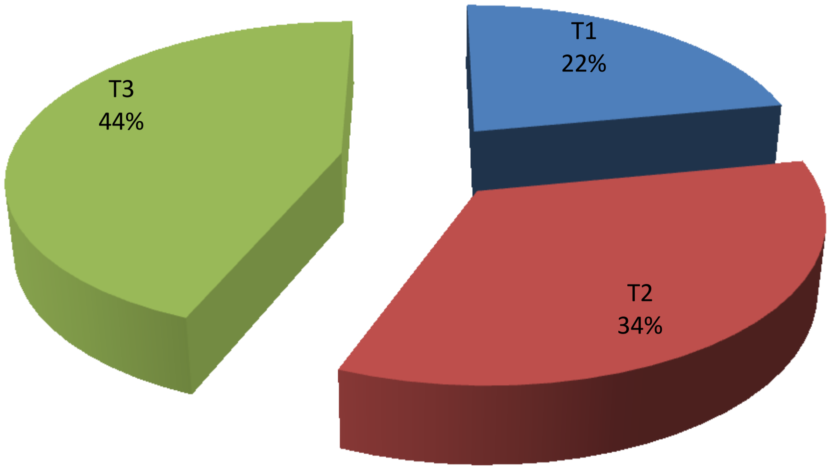

Figure 4: Relative abundance of plankton in the three treatments

4.4 Water Quality Monitoring

There were marginal differences on water temperature and pH among the treatments($p<0.05$). However, there were significant differences on dissolved oxygen and transparency among treatments (ANOVA; $F=1.58$, $p<0.05$). Furthermore, the post hoc test showed that there was significantly lower dissolved oxygen and transparency in ponds received manure with supplementary feed compared with other treatments ($P<0.05$). The lowest (24.36±0.60 cm) and highest (33.68±1.31 cm) transparency being recorded in ponds received manure alone and those received manure with supplementary feed respectively.Table 4 summarizes water quality results in fish ponds for the three treatments.

Table 4: Water quality parameters from fish ponds in three treatments

Parameter	Treatment		
	Feed (T_1)	**Manure (T_2)**	**Manure+Feed (T_3)**
Temperature (° C)	26.97±2.46^a	27.18±2.49^a	27.70±2.74^a
pH	8.04±0.03^a	8.03±0.03^a	8.04±0.04^a
DO (mg/l)	6.44±0.14^a	6.37±0.15^a	5.90±0.14^b
Transparency (cm)	33.68±1.31^a	28.36±0.60^b	24.81±0.49^c

Note: Different alphabetic superscripts in the same row indicate significant difference (P< 0.05).

4.5 Growth Performance of Chinese Cabbage

Table 5 summarizes the Growth performance parameters of Chinese cabbage in terms of diameter and length of leaves, number of leaves and yield. The results showed that there were significant differences in all parameters among treatments(ANOVA, P<0.05). Control had significantly lowest growth performance compared to all treatments. However, there were no significant differences in number of leaves and yields among treatments (P > 0.05). The results of post hoc test results showed that diameter and length of leaves showed no significant difference between treatments two (T_2) and three (T_3)(P > 0.05). But there is significant difference in terms of diameter between treatments (T_1) and (T_3).

Table 5: Growth performance and yield of Chinese cabbage

Parameter	Treatment			
	Control	**Feed (T_1)**	**Manure (T_2)**	**Manure+Feed(T_3)**
Diameter of leaves(cm)	9.27 ± 0.15^a	9.99± 0.12^b	10.54± 0.12^c	10.54±0.12^c
Length of leaves(cm)	16.95±0.24^a	18.33±0.20^b	19.30±0.20^c	18.76±0.20^{bc}
Number of leaves	3.53±0.21^a	4.92±0.22^b	4.86±0.22^b	5.32±0.20^b
Yield(kg/ha)	12,025.42^a	22,335.83^b	22,488.96^b	24,295.83^b

Note: Different alphabetic superscripts in the same row indicate significant difference (P< 0.05).

4.6 Chemical Composition of Fish and Vegetable from Integration System

Table 6 shows Body chemical composition of Nile tilapia and Chinese cabbage from three treatments. With the exception of dry matter, there were significant differences on ash contents, crude protein and ether extract from fish among the treatments (ANOVA, $P<0.05$). The highest crude protein content from fish were found in treatment (T_3) (55.9%) and the lowest in treatment one (T_1) (45.13%). Also, result showed that the highest ether extract (32.54%) was recorded in fish from treatment one (T_1) and lowest in treatment three (T_3) (11.63%). The highest ash content (25.82%) in treatment two (T_2) and lowest(12.78%) in treatment one (T_1)were recorded. For chemical composition of vegetable, results showed that there were no significant differences(ANOVA, $P>0.05$) among treatments. However, relatively higher ash contents, crude protein and etherextract were recorded in vegetables received water from ponds treated with manure alone (T_2) and manure with supplementary feed (T_3).

Table 6: Percentage chemical composition analysis of fish and vegetables from integration system

Product	Parameter	Treatment		
		Feed only (T1)	**Manure only (T2)**	**Manure and Feed (T3)**
Fish	Dry matter	95.66 ± 0.12^{a}	93.81 ± 0.59^{a}	95.56 ± 0.07^{a}
	Ash content	12.8 ± 0.74^{a}	25.8 ± 1.06^{b}	16.61 ± 2.09^{a}
	Crude protein	45.1 ± 0.26^{a}	52.9 ± 1.80^{b}	55.9 ± 1.40^{b}
	Ether extract	32.5 ± 0.33^{a}	13.4 ± 0.33^{b}	18.3 ± 3.41^{b}
Vegetable	Dry matter	91.82 ± 0.24^{a}	91.91 ± 0.23^{a}	91.87 ± 0.27^{a}
	Ash content	23.95 ± 1.75^{a}	29.74 ± 2.61^{a}	26.84 ± 0.79^{a}
	Crude protein	15.05 ± 1.56^{a}	17.79 ± 1.46^{a}	17.17 ± 1.72^{a}
	Ether extract	2.07 ± 0.21^{a}	2.40 ± 0.21^{a}	2.40 ± 0.28^{a}
	Crude fiber	17.55 ± 2.38^{a}	16.78 ± 2.53^{a}	18.81 ± 2.49^{a}

Note: Different alphabetic superscripts in the same row indicate significant difference ($P< 0.05$).

4.7 Economic benefits Analysis of the Systems

Table 7 summarizes the economic benefit of the fish-vegetable integrated system among the treatments. Moreover, treatment three (T_3) showed highest marginal revenue while the lowest was obtained from treatment two (T_2). The highest and lowest total cost was observed from treatment (T_3) and two (T_2) respectively. Results showed that treatment one (T_1) had significantly lowerbenefit-cost ratio (BCR) compared to treatment two (T_2) and three (T_3) (ANOVA, $P<0.05$).The highest benefit-cost ratio of(T_2, 2.37±0.06) was obtained from treatment two (T_2) followed by treatment three (T_3, 2.17±0.14). However, there were no significant different between treatment three (T_3) and treatment two (T_2) on benefit cost ratio (ANOVA, $P > 0.05$).

Table 7: Economic comparison between fish-vegetable integrated systems

	Indices	Unit	Treatments		
			(Feed)T_1	**(Manure)T_2**	**(Manure+Feed)T_3**
Revenue for Fish sub-system	Fish produced	Kg	171.1	144.1	313.3
	Price of fish/kg	TSh	7000	7000	7000
	Revenue	**TSh**	**1197700**	**1008700**	**2193100**
Revenue for Vegetable sub-system	Vegetable produced	Kg	65.65	66.1	71.45
	Price of vegetable/kg	TSh	500	500	500
	Revenue	**TSh**	**32825**	**33050**	**35,725**
	Total revenue of system	**TSh**	**1230525**	**1041750**	**2228825**
Variable cost for Fish sub-system	Fingerlings	TSh	225000	225000	225000
	Feed	TSh	500000	0	590000
	Labour	TSh	90000	90000	90000
	Manure	TSh	0	54000	54000
Variable cost for Vegetable sub-system	Pesticide	TSh	2000	2,000	2,000
	Labour	TSh	10000	10,000	10,000
	Seeds	TSh	1250	1,250	1,250
	Total variable cost of system	**TSh**	**828250**	**382250**	**972250**
Fixed cost for Fish sub-system	Pond construction	TSh	50000	50000	50000
	Fishing net	TSh	667	667	667
Fixed cost for vegetable sub-system	Watering can	TSh	2667	2667	2667
	Hoe	TSh	4000	4000	4000
	Total fixed cost	**TSh**	**57334**	**57334**	**57334**
Economic variables	**Total cost of the system**	**TSh**	**885584**	**439,584**	**1,029,584**
	Net Benefit of the system	**TSh**	**344 941**	**602 166**	**1 199 241**
	Benefit-Cost ratio (BCR)		**1.39±0.11[a]**	**2.37±0.06[b]**	**2.17±0.14[b]**

Note: Different alphabetic superscripts in the same row indicate significant difference at ($P < 0.05$).

CHAPTER FIVE

5.0 DISCUSSION

5.1 Growth Performance of Fish and Yield

Significantly higher growth performance and yield of fish from ponds fertilized and supplemented with feed reported from present study could be due to availability of natural food (planktons). This is a result of fertilizer and direct consumption of organic manure and supplementary feed. McNabb*et al*.(1990) reported that fertilization of fish pond increases the production of phytoplankton and zooplankton hence more food items available for fish. Jena *et al*. (1998) reported that the quality of formulated and natural feed influence the survival and growth of fish.Similarly, Diana *et al*. (1996) and Liti *et al*.(2001) reported higher growth rate of fish in ponds received manure and supplementary feed. Supplementary feeding is emphasized in fish culture because plankton may not be enough to meet protein requirement of fish(Brown *et al*., 2000).It has been suggested that higher gross fish production is probably supported by the role of both organic manure and supplementary feed (Abbas *et al.,* 2010).

However, during the first months of culture from January to May fish ponds treated with manure only had better growth performance than fish ponds treated with feed only. This is probably Nile tilapia (*Oreochromis niloticus*) at early stages of development prefer natural food (phytoplankton and zooplankton) than artificial feeds. It has been reported that addition of organic manure in *Oreochromis niloticus* ponds improves the utilization of supplemental feed and fish growth particularly during the early stages of growth (Victor, 1993). Fingerlings of *Oreochromis niloticus* feed mainly on phytoplankton, and their filtration rate is known to increase with increasing cell concentration (Turker *et al*., 2003). Nile tilapia feed primarily on phytoplankton at the beginning, and artificial food gains prominence with time (Abou *et al*., 2012), but the combination of the two improve significantly growth and yield.

5.2 Plankton Abundance

The abundance of plankton in the present study were found to be higher in ponds received chicken manure with supplementary feed probably due to availability of nutrient released by both inputs (poultry manure and supplementary feeds), such nutrients could be nitrogen and phosphorous. Kang'ombe (2006) reported higherplankton abundance in ponds received organic manure than ponds without manure. It has been reported that an increase in plankton biomass is often associated with nutrient enrichment (Smith 2003). Perumo and Anand (2008) reported that plankton are sensitive to an increase or decrease in nutrients. Furthermore, results reported by Abdel-Hakim *et al*. (2013) concur with the present study. These authors reported higher plankton abundance in fish ponds received artificial feed andpoultry manure compared to ponds received artificial feed only.

5.3 Water Quality Parameters

Water temperature, pH and dissolved oxygen values recorded in this study were within the optimal range for fish growth. Nile tilapia (*Oreochromis niloticus*) grows better in temperature rangingfrom 24 to 30^{0}C (Mang-umphan *et al*., 1998; Santhosh and Singh, 2007). Water temperature from present study ranged from 26.97 to 27.70 ^{0}C. The pH of natural waters is greatly influenced by the concentration of carbon dioxide which is an acidic gas (Boyd and Edna, 1997).Fish have an average blood pH of 7.4(Anita *et al*., 2013). Ideally, an aquaculture pond should have a pH between 6.5 and 9 which is optimum and conducive to fish life (Wurts and Durborow, 1992: Bhatnagar *et al*., 2004; Anita *et al*,. 2013). The recommended pH is comparable with the pH of 8.03-8.04 recorded from the present study.

According to Bhatnagar and Singh (2010) and Bhatnagar *et al*. (2004) dissolved oxygen greeter than 5mgl^{-1} support good fish production. The lowest dissolved oxygen recorded during the present study was from ponds received manure with supplementary feed (5.9mgl^{-1}). This isprobably due to decompositionof chicken manure used and feed remains,consequently resulting into depletion of dissolved oxygen within the fish pond. Transparency is the ability of light to penetrate and support photosynthesis and is the resultant effect of several factors including aspersions of plankton. According to Bhatnagar *et al*. (2004) and Santhosh and Singh (2007) a transparency of 15 to 80 cm is good for fish health in culture system while a transparency below 12 cm may causes stress to fish. The transparency values greater than 20 cm recorded from the present study from all treatment are within the recommended range.Boyd and Lichtkoppler (1979) pointed out that when light penetrates to greater depths it encourages growth of underwater macrophyte and therefore less plankton becomes available to serve as food for fish.

5.4 Growth Performance of Vegetable and Yield

The present findingsshowed that vegetable plots received water from fish ponds attained higher growth performance and yield compared to vegetable plots irrigated using water from stream. Length, diameter and number of leaves of Chinese cabbage and yield were higher in plots irrigated with water from fish ponds compared to those irrigated with stream water. Probably this could be due to higher contribution of nutrients from fish pond as a result of inputs (manure and feed).It has been reported that poultry manure is the most efficient way of adding nitrogen and otheressential nutrients in fish ponds (Ahmed *et al*., 2011). The results from this study are in agreement with other studies (see for example Alam *et al*., 2009; Shoko *et al.,* 2011). This study confirms the importance of integrating fish with other on-farm activities such as vegetables and chicken in increasing overall farm productivity. Integrated agro-aquaculture farming is ecologically sound because water from fish ponds improves soil fertility by increasing the availability of nitrogen and phosphorus (Dugan *et al*., 2006).

5.5 Chemical Composition of Fish and Vegetable

The present study have shown that fish from ponds received both manure and supplementary feed had significantly higher crude protein content, than fish from ponds received manure and feed only. The body composition of fish is mainly influenced by both the endogenous (e.g. gene) and exogenous (e.g. food) factors, which operate simultaneously (Shearer, 1994). The higher crude protein contents in fish might be contributed by supplementary feed and higher availability of natural food (zooplankton and phytoplankton). Relatively higher ash contents, crude protein and ether extract observed in vegetables received water from fish ponds is probably due to effect of nutrients from the pond caused by manure and supplementary feed.

5.6 Economic Benefits of the System

The highest total revenue and net benefit of the integrated agro-aquaculturefrom treatment three (T_3) in the present study was due to higher yields of fish and vegetable compared to other treatments.However, the highest benefit cost ratio (BCR) was obtained from ponds treated with manure only (T_2) and vegetable plots irrigated with water from these ponds. Dhirendra *et al*.(2004) reported significantly higher net income from tilapia culturedin fertilized pond with supplementary feeding which agreed with the present study.Abdel-Wahab and Abdel-Warith, (2013) reported thatfish feeds represent the major part of fish production, as it represents about 60 to 70% of fish farm operation cost and fish feed prices have increased significantly which reduced the profit margin of fish farming. Thus the use of manure to fertilized ponds may lead into reduction of supplementary feed and increase yield and income.

The highest benefit cost ratio (BCR) shown by treatment two (T_2) may indicate an economic benefit for rural communities with little resources. According to Abdel-Wahab and Abdel-Warith, (2013)chicken manure has been used extensively in small scale fish farming for increasing availability of natural food in pondhence reducing requirements of artificial feeds consequently leading to reduction on production costs and therefore improving farm income. However, for better fish growth performance and yield additional feed to optimize production of fish as well as vegetables is emphasized. Li and Yakupitiyage (2003) reported that supplemental feed is required to increase fish yield in fertilized ponds. The present study confirms that integrated agro-aquaculture using manure and supplementary feed improve income. This proves that integrated fish-crops are not only technically feasible but also economically viable.According to Alam *et al*. (2009) integrated production approach with poultry, fish and vegetables lead to improving diversification of food production and income generation of the resource poor farm households.Furthermore, economic analysis from the present study suggests that using water from fish ponds increase vegetable productivity hence increase economic returns.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the findings reported in the present study the following conclusions are drawn:

i. Nile tilapia (*Oreochromis niloticus*) in ponds fertilized and received supplementary feed in fish-vegetable integration system exhibited the highest growth performance and yields than those ponds fed and treated with manure only.
ii. Chinese cabbage (*Brassica rapachinensis*)irrigated with water from fish ponds attained significantly higher growth performance and yields than those plots irrigated with stream water.
iii. The highest revenue and net benefit was obtained fromfish ponds received manure with supplementary feed and vegetable plots received water from this treatment.
iv. Fish ponds received manure only attained highest benefit cost ratio (BCR) hence more economically viable than other treatments.

6.2 Recommendations

Based on the findingsin the present study the following recommendations are made:

i. Policy makers should promote the use of integrated agro-aquaculture (poultry-fish-crops) system in order to increase overall farm production and uplift people's livehoods mostly in rural communities.
ii. Fish farmersshould be encouraged to use integrated agro-aquaculture (poultry-fish-crops) innovation for improving diversification of food production and source of income generation.
iii. Further studies should be conducted to evaluate the reasons for slow adoption of integrated agro-aquaculture (IAA).

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APPENDICES

Appendix 1: ANOVA for initial body weight of fish (*Oreochromis niloticus*) among treatments.

Variables		Sum of squares	df	Mean square	F	Sig.
IBW	Between Groups	5.129	2	2.56	1.056	0.349
	Within Groups	1238.452	510	2.428		
	Total	1243.581	512			

Appendix 2: ANOVA for final body weight of fish (*Oreochromis niloticus*) among treatments

Variables		Sum of squares	df	Mean square	F	Sig.
FBW	Between Groups	303606.035	2	151803.018	821.787	0.000
	Within Groups	94208.807	510	184.723		
	Total	397814.842	512			

Appendix 3: ANOVA for daily weight gain of fish (*Oreochromis niloticus*) among treatments

Variables		Sum of squares	df	Mean square	F	Sig.
DWG	Between Groups	87.270	2	43.635	168.852	0.000
	Within Groups	662.072	2562	0.258		
	Total	749.342	2564			

Appendix 4: ANOVA for weight gain of fish (*Oreochromis niloticus*) among treatments

Variables		Sum of squares	df	Mean square	F	Sig.
WG	Between Groups	305671.281	2	152835.640	808.448	0.000
	Within Groups	96414.606	510	189.048		
	Total	402085.886	512			

Appendix 5: ANOVA for specific growth rate of fish (*Oreochromis niloticus*) among treatments

Variables		Sum of squares	df	Mean square	F	Sig.
SGR	Between Groups	66.683	2	33.341	7.899	0.000
	Within Groups	10814.531	2562	4.221		
	Total	10881.213	2564			

Appendix 6: ANOVA for survival rate of fish (*Oreochromis niloticus*) among treatments

Variables		Sum of squares	df	Mean square	F	Sig.
SR	Between Groups	91.533	2	45.766	3.138	0.117
	Within Groups	87.505	6	14.584		
	Total	179.038	8			

Appendix 7: ANOVA for feed conversion ratio for fish (*Oreochromis niloticus*) among treatments

Variables		Sum of squares	df	Mean square	F	Sig.
FCR	Between Groups	0.050	1	0.050	71.593	0.000
	Within Groups	0.239	340	0.001		
	Total	0.289	341			

Appendix 8: ANOVA for water temperature in fish ponds among treatments

Variables		Sum of squares	df	Mean square	F	Sig.
Temp	Between Groups	20.702	2	10.315	1.576	.209
	Within Groups	1399.324	213	5.570		
	Total	1420.026	215			

Appendix 9: ANOVA for water pH in fish ponds among treatments

Variables		Sum of squares	df	Mean square	F	Sig.
pH	Between Groups	0.007	2	0.004	0.042	0.959
	Within Groups	18.276	213	0.086		
	Total	18.283	215			

Appendix 10: ANOVA for dissolved oxygen in fish ponds among treatments

Variables		Sum of squares	df	Mean square	F	Sig.
DO	Between Groups	12.562	2	6.281	4.666	0.010
	Within Groups	286.699	213	1.346		
	Total	299.262	215			

Appendix 11: ANOVA for water transparency in fish ponds among the treatments

Variables		Sum of squares	df	Mean square	F	Sig.
Transparency	Between Groups	3974.714	2	1987.357	35.749	0.000
	Within Groups	11841.044	213	55.592		
	Total	15815.758	215			

Appendix 12: ANOVA for leaf diameter of vegetable

Variables		Sum of squares	df	Mean square	F	Sig.
Diameter	Between Groups	1250.857	3	416.952	19.460	0.000
	Within Groups	115483.918	5390	21.426		
	Total	116734.775	5393			

Appendix 13: ANOVA for leaf length of vegetable among treatments

Variables		Sum of squares	df	Mean square	F	Sig.
Length	Between Groups	3404.968	3	1134.989	19.612	0.000
	Within Groups	312156.720	5394	57.871		
	Total	315561.688	5397			

Appendix 14: ANOVA for number of leaves of vegetable among treatments

Variables		Sum of squares	df	Mean square	F	Sig.
Leave	Between Groups	523.822	3	174.607	13.259	0.000
	Within Groups	15104.991	1147	13.169		
	Total	15628.813	1150			

Appendix 15: ANOVA for yield of Chines cabbage among treatments

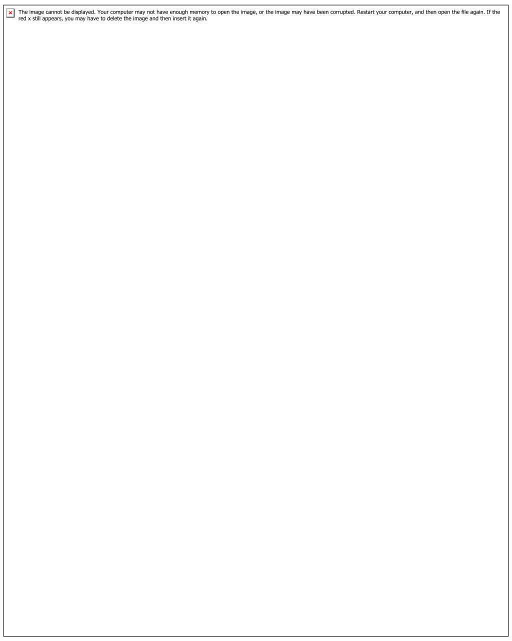
Variables		Sum of squares	df	Mean square	F	Sig.
Yield	Between Groups	67.278	3	22.426	2.745	0.054
	Within Groups	359.451	44	8.169		
	Total	426.729	47			

Appendix 16: ANOVA for yield of fish (*Oreochromis niloticus*) among treaments

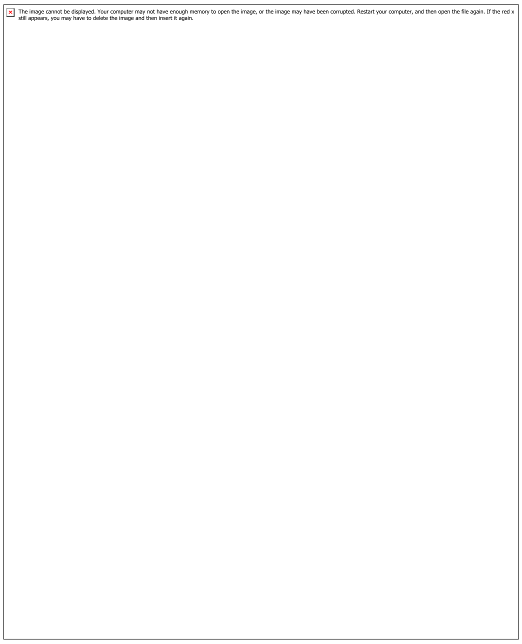
Variables		Sum of squares	df	Mean square	F	Sig.
Yield	Between Groups	5508.720	2	2754.360	38.077	0.000
	Within Groups	434.020	6	72.337		
	Total	5942.740	8			

Appendix 17: ANOVA for benefit cost ratio among treatments

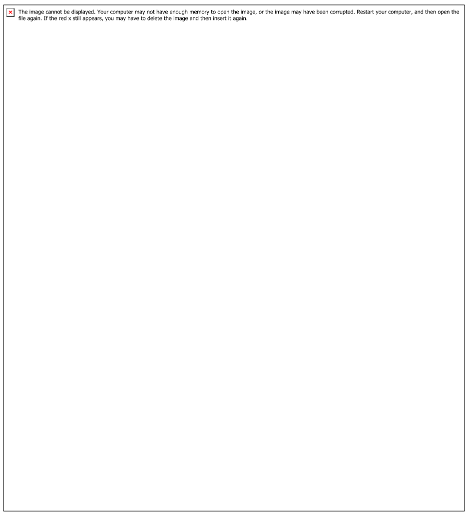
Variables		Sum of squares	df	Mean square	F	Sig.
BCR	Between Groups	4.907	2	2.453	44.228	0.000
	Within Groups	0.333	6	0.055		
	Total	5.240	8			



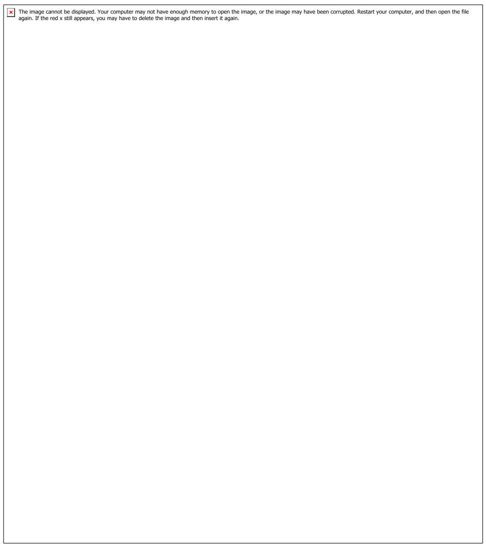
Fish weight recorded at every month



Vegetable data collection



Vegetable plot



Water quality measurement of fish pond