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Characterization of fish farming systems in Kiambu and Machakos counties, Kenya

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Abstract
Fish farming systems in Kiambu and Machakos counties, Kenya were studied; challenges to production were identified and recommendations to boost fish production were suggested in this research. Two counties were targeted which are Machakos and Kiambu county. Data were obtained through a field survey, questionnaires and personal observations between September and October 2011. The study covered the key areas of fish farming: general farm details, number of ponds, number of fingerlings stocked, housing, type of culture practiced, feeds and feeding practices, influence of Economic Stimulus Program (ESP) on service delivery and management practices, Constraints to production and recommendations appertaining to the key production challenges. Results showed that fish farming in both Kiambu and Machakos county was practiced by farmers who had had attained atleast primary level of education. The employment status of fish farmers in Kiambu and Machakos counties showed that majority of the respondents (79.3% and 54% in Kiambu and Machakos County respectively) were self-employed in agriculture. Fish farming was practiced by a relatively large proportion of farmers below 50 years of age in Kiambu Machakos counties. Of the 250 respondents interviewed, 85.3% and 75% in Kiambu and Machakos counties respectively were recruited through the ESP. The main source of information on fish farming was government extension agents as reported by 93.8% and 92% of ESP farmers in Kiambu and Machakos counties respectively. Stocking of Nile tilapia in mixed sex tilapia in monoculture was the most dorminant culture method and fish were mainly stocked in earth ponds. Farmers in Kiambu and Machakos counties used complete or formulated commercial feeds for feeding the fish. Formulated fish feeds were mainly supplied by the government. Majority of the ESP farmers (64.8% and 78.7%) in Kiambu and Machakos counties respectively relied on government extension to provide information on pond management.

Keywords: *fish farming; pond culture; fish feeding; economic stimulus program*.

1. Introduction
Kenya's fisheries sector has the potential to contribute significantly to the national economy through employment creation, earning foreign exchange, poverty reduction and food security provision. Fish production in the country has been declining since 1999 when the highest quantity (214,709 MT) of fish was landed. The values of fish products have been increasing steadily (MFD, 2010). Capture fisheries in Kenya has been rapidly declining as result of both environmental degradation of the main water bodies and increasing fishing pressure leading to over-fishing.

Aquaculture is one of the fastest growing food production sectors in the world (FAO 1997). Fish production has increased in developing countries, while the numbers of species cultured have also increased. Aquaculture in developing countries has been viewed as a means of improving food security and supplementing income for rural families. In many countries, particularly in Africa, aquaculture is done at subsistence level and the little surplus production is sold in the rural markets (FAO, 1997).

There is no information on fish farmers' management practices such as the fish species kept, type and sources of feed used, common fish diseases, and opportunities and challenges faced by fish farmers. There is also no information on the quality of water and feeds used in fish farming. Such information is useful for farmers to improve on their practices and for policy makers to design programs which address the challenges faced by the farmers and exploit the opportunities available. This study aims to fill this gap.

The overall objective of this study was to characterize fish farming systems in Kiambu and Machakos counties in Kenya. Evaluate socio-economic characteristics of fish farmers in

Kiambu and Machakos counties of Kenya and determine the influence of the economic stimulus program on service delivery and fish management practices in the two counties.

2. Materials and Methods

A. Sources of Information and Period of Study

Data were obtained through a field survey, structured-questionnaire administration and personal observations between August and September 2011.

B. Scope

Respondents' socioeconomic characteristic relevant to explaining adoption of fish farming was collected including age, gender of household head, marital status, level of education, occupation and farm size. Data on fish management practices included: Stocking rates, farm size in acres, pond size, type and number of fingerlings stocked, type of pond and number of ponds and fish species stocked. Pond management practices were assessed using data on pond fertilization and topping up of water in the pond. Observations were also made on the colour of the pond water and analysis done to determine the suitability of water for fish farming. Data on pond fertilization were also collected including the type of fertilizer used and the frequency of fertilization. Percentage of ponds using a certain kinds of fertilizer and manure were determined and correlated with the type of feeds in order to determine the level of intensification and integration. Data were collected on type of feed fed to fish, amount fed daily and the number of times feeding is done, source of fertilizer, type and frequency of fertilization. Feed samples were obtained for sigma feeds which was supplied by government, king feeds and any other type of feed fed to the fish by the farmers.

C. Study Area

The study was carried out in Kiambu and Machakos counties in Kenya. The area was chosen because of the following reasons: (i) the two counties border the Nairobi metropolitan area which is an important fish market; (ii) the two counties had a short history of fish farming, (iii) in both counties, the farmers practice mixed farming, and (iv) for comparison purposes: Machakos county is drier than Kiambu county.

D. Sample Size

Households were the sampling units used in the study. Samples were purposively drawn from the sampling frame provided by District Fisheries Officers in the respective study areas.

The area of study within the county was purposively chosen according to the sampling frame provided by the district Agricultural Officer. A semi-structured questionnaire was prepared and given to aquaculture experts to check content and validity. After incorporating experts' comments, it was pre-tested, and then a final version incorporating the pre-test results was produced. All questionnaires were administered through face-to-face interviews to 250 farmers by the researcher with the help of five enumerators.

E. Data Management and Analysis

By the end of the research period, 250 questionnaires had been delivered. All the data were capture, stored analyzed using SPSS Version 16. Two analyses were made: descriptive analyses (by use of means, modes, standard deviations, variance, percentages, and frequencies) and the inferential analyses (by use of t-test). The former provided the descriptive and documentation of the state of affairs as they were, while the latter indicated statistically significant relationships between the variables and in the testing of the specific objectives. The variables tested included, time of harvesting, Farm gate price in Kenya shillings, land size and frequency of pond refilling, price of harvested fish and number of fingerlings stocked. Means, standard deviation and p values were used to test differences that existed. All this were tested at the probability level of p=0.05

3. Results and Discussions

A. Socio-economic characteristics of fish farmers in Kiambu and Machakos Gender of respondents

Table I shows that the majority of the fish farmers in Kiambu and Machakos counties were men (80 percent, 74 percent, respectively). This is in agreement with the findings by Ellen and Gardner (2009) [5] on the challenges facing women in Burkina Faso.

Table 1: Distribution of respondents by gender in Kiambu and Machakos counties.

	Kiambu County		Machakos County	
Gender	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Male	120	80	74	74
Female	30	20	26	26
Total	150	100	100	100

B. Age of respondents

Table II shows the age of fish farmers in the two counties. The mean age of fish farmers interviewed was 45.7±13.19 years in Machakos county and 48.4±11.99 years in Kiambu county. The Table further shows that fish farming was practiced by a relatively large proportion of farmers below fifty years of age – 61.7 percent in Kiambu and 69.4 percent – both categories combined in Machakos counties respectively under the ESP. Wetengere (2009) [23] reported that younger farmers in Tanzania were more likely to try new technologies and were capable of doing laborious activities like pond construction, pond repair and total harvest. The mean ages obtained have important implications on future adoption of fish farming as a commercial enterprise since the youth are more likely to practice it over a longer period of time than the older farmers.

Table 2: Distribution of age of the respondents in Kiambu and Machakos counties.

Kiambu County				
	ESP		**Self-funded**	
Age category(years)	**Frequency**	**Percentage**	**Frequency**	**Percentage**
26 – 40	36	28.1	8	36.4
41 – 50	43	33.6	4	18.2
51 – 60	30	23.5	7	31.8
Above 60	19	14.8	3	13.6
Total	128	100	22	100
Machakos County				

	ESP		Self-funded	
Age category(years)	**Frequency**	**Percentage**	**Frequency**	**Percentage**
26 – 40	34	45.4	9	36.0
41 – 50	18	24.0	8	32.0
51 – 60	13	17.3	4	16.0
Above 60	10	13.3	4	16.0
Total	75	100	25	100

ESP- Economic Stimulus Program

C. Employment status of fish farmers

Table 4.3 shows the employment status of fish farmers in Kiambu and Machakos counties. Majority of the respondents (79.3 percent and 54 percent in Kiambu and Machakos County respectively) were self-employed in agriculture, while 20.7 percent were self employed in non-farm enterprise such as formal employment, domestic work and casual labour in Kiambu County. Machakos County had similar trends having 46 percent self employed in non-farm enterprise. These results tally with what is reported in the 2010 Government of Kenya Development Plan (Republic of Kenya, 2011) [20] which shows that over 70 percent of Kenyans are employed in the informal sector, particularly agriculture.

In this study, it was also observed that respondents aged over 60 years who had retired from formal employment had settled in farming, and particularly fish farming. This corroborates the results obtained by Oseni *et al.*, (2011) [18] who reported similar trends in Nigeria.

Table 3: Employment status of fish farmers in Kiambu and Machakos counties

Kiambu County			Machakos County	
Main occupation	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Self employed in agriculture	119	79.3	54	54
Self employed in non-farm enterprise	31	20.7	46	46
Total	150	100	100	100

D. Education level of fish farmers

All the fish farmers had formal education (Table IV). Only 23.8 percent and 16 percent of the fish farmers in Kiambu and Machakos county respectively, did not complete primary education. 25.2 percent and 45.3 percent of the farmers in Kiambu and Machakos counties respectively, had attained a minimum of primary school education. The results presented in table 4.4 show the percentage who had at least primary level of education was highest for farmers who did fish farming under the ESP. The results show that only 13 and 3 percent of fish farmers under ESP and Self funded respectively in Kiambu county had not completed primary education. In Machakos county only 3 percent of farmers in both categories had not completed primary level of education. This could be due to the fact that fish farming was a relatively new venture and only farmers who had ready access to information and were willing to take risks, had adopted it since farmers with higher levels of education are more responsive to new technologies. This observation was in agreement with that of Kimenye (2005) [10], who showed that increase in farmer's level of formal education increased the probability to plant an improved crop variety. The fact that majority of the fish farmers had formal education imply that dissemination of information on fish farming is likely to yield positive results in terms of better management and improved productivity. The farmers who were recruited by the government to do fish farming had higher levels of education. This shows that the recruitment of the farmers might have been biased. Shitote *et al.,* (2013) [21] reported that fish farming in Western Kenya was practised by farmers with at least primary level of education.

Table 4: Level of formal education among respondents in Kiambu and Machakos counties

Kiambu County				
	ESP		**Self-funded farmers**	
Education level	**Frequency**	**Percentage**	**Frequency**	**Percentage**
University/college	3	2.3	2	9.1
University/college student	11	8.6	2	9.1
Secondary	87	68.0	8	36.4
Technical/polytechnic	5	3.9	3	13.6
Primary	9	7.0	4	18.2
Never completed primary	13	10.2	3	13.6
Total	128	100	22	100
Machakos County				
	ESP		**Self-funded**	
Education level	**Frequency**	**Percentage**	**Frequency**	**Percentage**
University/college	3	4.0	2	8.0
University/college student	10	13.4	5	20.0
Secondary	28	37.3	12	48.0
Technical/polytechnic	3	4.0	1	4.0
Primary	28	37.3	2	8.0
Never completed primary	3	4.0	3	12.0
Total	75	100	25	100

ESP- Economic Stimulus Program

E. Total farm size and land use

The average land size was 2.5±3.47 and 4.27±4.78 acres in Kiambu and Machakos Counties respectively. This was not statistically different between the two counties (p=0.05)(Table VIII) Land was primarily used for crops and livestock production.

F. Influence of the Economic Stimulus Program on fish farming in Kiambu and Machakos counties

Distribution of respondents under ESP and Self- funded fish farmer categories

Of the 250 respondents interviewed, 85.3 percent and 75 percent in Kiambu and Machakos counties respectively were recruited through the ESP (Table V). The rest of the farmers (14.7 percent in Kiambu and 25 percent in Machakos) started fish farming using their own funds and were doing it before the onset of the FFEPP. This study also established that 89.3 percent and 80 percent of the fish ponds in Kiambu and Machakos respectively were established between 2009 and 2010 financial years which is the period when the Economic Stimulus Program was rolled out.

These findings are consistent with reports by the Ministry of Fisheries Development which gave the number of stocked fish ponds to be 666 and 598 ponds in Kiambu and Machakos districts respectively, in its ESP implementation report of January 2011 (GoK, 2010) [6]. Musa *et al.,* (2012) [15] indicated that 92% of ponds in Western Kenya were stocked in the year 2010 in comparison to four percent in 2009. The researcher pointed out that the high number of ponds stocked in 2010 may be attributed to the FFEPP which supported farmers in constructing and stocking of the ponds with ESP funds from the Government of Kenya (Musa *et al*., 2012) [15].

Table 5: Distribution of respondents with respect to ESP in Kiambu and Machakos counties

	Kiambu County		Machakos County	
Category of farmer	**Frequency**	**Percentage**	**Frequency**	**Percentage**
ESP funded	128	85.3	75	75
Self-funded	22	14.7	25	25
Total	150	100	100	100

G. Respondents' motivation for engaging in fish farming

In Kiambu county 79.6 and 91 percent of ESP and self-funded farmers, respectively kept fish mainly for commercial purposes while in Machakos county it was 56 and 72 percent respectively (Table VI). Another 7.8 and 4.5 percent for ESP and self funded farmers, respectively in Kiambu county and 38.7 and 20 percent in Machakos county kept fish for home consumption. The rest (6.3 percent in Kiambu and 4 percent-both ESP and self funded categories combined in Machakos) started the enterprise because it was a government initiative under the ESP. Charo-Karisa and Gichuri (2010) [1] reported that the FFEPP started in mid-2009 aimed at increasing production of farmed fish from 4000 MT to over 20,000 MT in the medium term and over 100,000 MT per year in the long term. The latter observation suggests that some of the farmers did not own the government-driven fish farming enterprise. However, majority of the fish farmers in both counties believed that fish farming was profitable and could contribute to their income.

Table 6: Motivation of respondents engaging in fish farming in Kiambu and Machakos counties

Kiambu County				
	ESP farmers		**Self-funded farmers**	
Motivation	**Frequency**	**Percentage**	**Frequency**	**Percentage**
To generate income	102	79.6	20	91.0
Hobby	8	6.3	1	4.5
Home consumption	10	7.8	1	4.5
Government's initiative	8	6.3	0	0
Total	128	100	22	100
Machakos County				
	ESP		**Self-funded**	
Motivation	**Frequency**	**Percentage**	**Frequency**	**Percentage**
To generate income	42	56.0	18	72.0
Hobby	1	1.3	2	8.0
Home consumption	29	38.7	5	20.0
Government's initiative	3	4.0	0	0
Total	75	100	25	100

ESP- economic stimulus program

H. Influence of ESP on Pond management and fish farming inputs

Labor sources and use

The FFEPP supplied farmers with fingerlings, fish feeds and hired labour for the construction of the ponds through the '*Kazi Kwa vijana'* Programme. In both Kiambu and Machakos counties, the average quantity of labour hired for construction of one pond was 9.1 ± 2.43 persons while the average cost of construction of a pond was KShs 21,680 ± 14534.18. However, not every farmer in the ESP benefited from government funding to hire labuor to dig the ponds. About 37 and 31 percent of ESP farmers in Kiambu and Machakos counties respectively used their own labour to dig the ponds (VII). In Machakos county self-funded farmers were also funded by the government to construct the fish ponds. All the non-ESP farmers hired their own labour. The cost of labour has important implications in terms of future adoption of fish farming and the size of the pond farmers construct since the larger the pond the higher the cost of labour.

Table 7: Sources of labour used for pond construction in Kiambu and Machakos counties

	Source of Labour				
		ESP		Self-funded	
County	Labor source	Frequency	Percentage	Frequency	Percentage
Kiambu	Government hired	81	63.3	3	13.6
	Hired by the farmer	47	36.7	19	86.4
	Total	128	100	22	100
Machakos	Government hired	52	69.3	15	60.0
	Hired by the farmer	23	30.7	10	40.0
	Total	75	100	25	100

Table 8: Independent t test for variables influenced by ESP funding

Variable	ESP funded farmers	Self-funded farmers	p-value	SEM
Frequency of topping up	1.84	1.98	.611	.268
Frequency of fertilization	2.37	2.79	.032*	.192
Age of respondent	47.20	47.57	.853	2.033

Values with asterisk (*) denote significant different of the variables between the two categories of farmers at p=0.05

Table 9: Independent test for variables different between the two counties

Variable	Kiambu county	Machakos county	p-value	SEM
Land size(acres)	4.27	5.93	.215	1.33
Frequency of topping up water	2.03	1.62	.052	.212
Number of fingerlings stocked	1066.53	876.29	.003*	64.349
Time of harvesting(months)	9.50	6.88	.000*	.321
Farm gate price (Ksh)	180.8	131.90	.000*	9.555

Values with asterisk denote significant different of the variables between the two counties at p=0.05

I. Sources of fingerlings in Kiambu and Machakos counties

Majority of the fish farmers under the ESP programme (84.4 and 68 percent) in Kiambu and Machakos County respectively were provided with fingerlings by the government (table X). Many of the self-funded farmers in Machakos County were provided with fingerlings by the government which was not the case in Kiambu County. Musa *et al.,* (2012) [15] noted that one of the principal activities of the FFEPP was to revamp fish hatcheries across the country to ensure sufficient production of fingerlings to stock the ponds. Other sources of fingerlings included; private hatcheries, rivers and supply by NGOs supporting fish farming.

Table 10: Sources of fingerlings in Kiambu and Machakos counties

Kiambu County				
	ESP		Self-funded	
Sources of fingerlings	Frequency	Percentage	Frequency	Percentage
Government supplied	108	84.4	3	13.7
Purchased	20	15.6	18	81.8
Borrowed from neighbors	-	-	-	-
River	-	-	-	-
Supplied by NGO	-	-	1	4.5
Total	128	100	22	100
Machakos County				
	ESP		Self-funded	
Sources of fingerlings	Frequency	Percentage	Frequency	Percentage
Government supplied	51	68.0	10	40.0
Purchased	20	26.7	11	44.0
Borrowed from neighbors	3	4.0	1	4.0
River	0	-	3	12.0
Supplied by NGO	1	1.3	0	0
Total	75	100	25	100

ESP- Economic stimulus program

J. Supply of fish feeds and pond liners

Formulated fish feeds were mainly supplied by the government. Majority of farmers however complained of lack of feeds implying that the government was not a reliable source. Farmers purchased inorganic fertilizers and supplementary feeds like maize bran and fish meal from the local agrochemical stockists.

Lining of ponds is done to reduce seepage in porous soils. Pond liners were from dealers who are mainly in Nairobi. The major challenge in acquiring the liners was that they were very expensive costing KShs. 30,000 for a 300m^2 liner and many fish farmers could not afford them.

K. Sources of extension services to fish farmers

Majority of the ESP farmers (64.8 and 78.7 percent) in Kiambu and Machakos counties respectively (table XI) relied on government extension services to provide information on fish farming. Among self-funded farmers, neighbours played an important role as source of information on fish farming. This was particularly evident in Machakos County. There was disparity in sources of information for the self-funded farmers. 18.2 percent in Kiambu and 72 percent in Machakos County of

the self-funded farmers indicated that they obtained information on fish farming from the government. This category of farmers also relied on information obtained from other sources like neighbours and mass media.

Table 11: Sources of extension services to fish farmers in Kiambu and Machakos counties

Kiambu County				
	ESP		Self-funded	
Source of information	Frequency	Percentage	Frequency	Percentage
Government extension	83	64.8	4	18.2
Neighbors	18	14.1	8	36.4
Seminars	20	15.6	7	31.8
Mass media	7	5.5	3	13.6
Total	128	100	22	100
Machakos County				
	ESP		Self-funded	
Source of information	Frequency	Percentage	Frequency	Percentage
Government extension	59	78.7	18	72.0
Neighbors	4	5.3	4	16.0
Seminars	3	4.0	1	4.0
Mass media	9	12.0	2	8.0
Total	75	100	25	100

Seminars played a role in transmission of fish farming technologies especially in Kiambu county. The farmers indicated that most of the seminars were organized by government extension officers. The farmers who started fish farming prior to the ESP programme obtained information from neighbours and friends, mass media and NGOs. According to Quagrainie *et al.,* (2009) [9], the increase in awareness among farmers in Kenya about the viability of farming fish as an alternative agricultural enterprise was as a result of initiatives by some Non-governmental organization in technology transfer programs toward improving fish farming.

L. Fish species and culture method

The most popular species stocked in Kiambu County by both ESP and self-funded fish farmers was tilapia which was by 96.1 percent and 90.9 percent of farmers under ESP and self-funded categories, respectively. In Machakos County, ESP farmers formed 94.6 percent for those who stocked tilapia. De Silva (1993) [2] noted that *O. niloticus* is one of the widely farmed tilapia species in tropical countries because it feeds low in the food chain and also consumes a wide variety of materials.

Tilapia/catfish polyculture was done by 9.1 percent and 12 percent of farmers in Kiambu and Machakos counties, respectively among self-funded category of farmers (Table XII). Machakos County had a higher percentage of farmers practicing catfish monoculture because of market preference for that species and also because fingerlings were easily obtained from river Athi.

The average price of a tilapia fingerling supplied by the government was KShs 3 although most of the farmers were supplied with fingerlings by the government. Crayfish was only found in Kiambu County where it was grown by 0.8 percent of the farmers interviewed. The study also found that the average pond area in Machakos and Kiambu County was $300M^2$ and that 1000 fingerlings were stocked per pond giving a stocking rate of approximately 3 fingerlings per square meter. The numbers of fingerlings stocked was statistically different between the two counties (p=0.05) (Table IX). Musa *et al.,* (2012) [15] also reported similar findings in western Kenya except for crayfish.

Availability of fingerlings is one of the pre-requisites of fish farming. This was supported by the fact that over 50 percent of farmers in the two counties cited availability of the fingerlings and recommendation by the government as the main reason for their choice of fish species. In both regions, the practice was to introduce a few mature cat fish into tilapia ponds after 4 months of stocking tilapia to control the population of tilapia which reproduce very fast after reaching sexual maturity which is as early as 3 months (Diana *et al*., 1996) [4].

Table 12: Type of fish culture practiced in Kiambu and Machakos counties

Kiambu County				
	ESP		Self-funded	
Type of culture	Frequency	Percentage	Frequency	Percentage
Tilapia monoculture	123	96.1	20	90.9
Tilapia/catfish polyculture	0	0	2	9.1
Catfish monoculture	4	3.1	0	0
Cray fish	1	0.8	0	0
Total	128	100	22	100
Machakos County				
	ESP		Self-funded	
Type of culture	Frequency	Percentage	Frequency	Percentage
Tilapia monoculture	71	94.6	14	56.0
Tilapia/catfish polyculture	2	2.7	3	12.0
Catfish monoculture	2	2.7	8	32.0
Cray fish	-	-	-	-
Total	75	100	25	100

ESP- Economic Stimulus Program

About 51 and 28 percent of farmers in Kiambu and Machakos counties respectively stated that the main reason for choosing to rear a certain fish species was because it was promoted by the government which also guaranteed the availability of the fingerlings for those farmers who were under the ESP. With regard to ESP farmers, 13.6 and 16 percent in Kiambu and Machakos counties stocked tilapia because it was promoted by the government. However, fish farmers in Kiambu county seemed to have already made up their minds to keep tilapia monoculture, which shows that fish farming and consumption might not have been as new as it was in Machakos county.

Over 40 percent of farmers in both counties preferred tilapia culture due to its consumer preference the species. A relatively large percentage of farmers (28 percent in Machakos County)

reared tilapia because of its early maturity compared to only 2.3 percent in Kiambu County (Table 4.16). On average, tilapia in Machakos County reached table size at 6 months compared to 9 months in Kiambu County because of the higher water temperatures in Machakos. This was statistically different between the two counties (p = 0.05) (Table 4.12)

Table 13: Reasons for preference of tilapia to other fish species in Kiambu and Machakos counties

Kiambu County				
	ESP		Self-funded	
Reason	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Recommended by government	65	50.8	3	13.6
Market preference	51	39.9	16	72.8
Decision by NGO	0	0	1	4.5
Availability of fingerlings	9	7.0	2	9.1
Early maturity	3	2.3	0	0
Total	128	100	22	100
Machakos County				
	ESP		Self-funded	
Reason	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Recommended by government	21	28.0	4	16.0
Market preference	29	38.7	11	44.0
Decision by NGO	-	-	-	-
Availability of fingerlings	16	21.3	6	24.0
Early maturity	9	12.0	4	16.0
Total	75	100	25	100

ESP- Economic Stimulus Program

J. Fish holding structures

The most common type of pond was the earth pond where Kiambu County had 74.2 percent and Machakos County had 42.7 percent among the ESP farmers. Machakos County had the highest number of liner ponds at 56 percent against 25 percent in Kiambu County (Table XIV). However, 59.1 percent of self-funded farmers in Kiambu County had liner ponds possibly indicating the willingness of these farmers to invest more in fish farming. The liner ponds were more common in Machakos County because of the scarcity of water in this region, low amounts of rainfall, high rates of evaporation and the poor water holding capacity of soils in the county. Therefore, the liners were used as a strategy of conserving the pond water. In a similar survey in Western Kenya, Musa *et al.,* (2012) [15] found that most farmers had earthen ponds. The prevalence of earthen ponds showed that the soils in western Kenya have good water retention or that farmers were poor and could not afford pond liners.

Earth ponds lose a lot of water through seepage and the problem of water scarcity makes refilling of the pond difficult hence the trend of moving towards investment in liner ponds. The soils in Machakos were also poor compared to Kiambu in terms of water holding capacity and there was a high rate of evaporation. However, on average, earth ponds were the most common pond types compared to liner, concrete ponds and tanks. This finding is consistent with that of Machena and Moehl (2001) [14] who noted that earth ponds are the dominant fish holding structures in Africa.

Table 14: Pond types used by fish farmers in Kiambu and Machakos counties

Kiambu County				
	ESP		Self-funded	
Pond type	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Liner pond	32	25.0	13	59.1
Earth pond	95	74.2	7	31.8
Concrete pond	-	-	-	-
Tank culture	1	0.8	2	9.1
Total	128	100	22	100
Machakos County				
	ESP		Self-funded	
Pond type	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Liner pond	42	56.0	11	44.0
Earth pond	32	42.7	12	48.0
Concrete pond	1	1.3	2	8.0
Tank culture	-	-	-	-
Total	75	100	25	100

Key: ESP- Economic Stimulus Program

K. Pond stocking

The average number of fingerlings stocked per pond in Kiambu County was 1064.57±541.96 fingerlings and 876.29±421.28 in Machakos County. This was mainly because most of the farmers got the fingerlings from the government which supplied 1000 fingerlings for a 300m^2 fish pond. In this study, only 10 percent of the fish farmers stocked less than 1000 fingerlings and these were self-funded who procured the fingerlings using their own resources.

L. Fish production cycle and systems

The average production cycle was 9.36 months in Kiambu and 6.88 months in Machakos. The means were significantly different between the two counties (p=0.05) (Table IX). This difference could be due to differences in water temperatures in

the two counties since harvesting in the two counties is informed by fish size. This was also supported by the fact that 31 percent of the farmers in Kiambu County harvest after 12 months while in Machakos 53 percent of the farmers harvest at 6 months of age. Tilapias reach table size maturity (180 – 200) grams between 6 – 7 months with the right temperature and good management and the right species (Popma & Rodriquez, 2000).

Terchert-Coddington and Green, (1997) [22] defined semi-intensive system as one where production is done in earthen ponds with nutrient input limited to manure and supplemental feeds with no aeration or water exchange.This fish production system was the most common in both counties with 98.4 and 46.7 percent of ESP farmers in Kiambu and Machakos counties practising it respectively (Table XV). This production system was characterized by keeping fish in ponds which were fertilized with organic manures (especially crop residues and livestock manure) with little or no use of commercial fertilizers. Supplementary feeding was done using complete or home made feeds. Lovshin, (2000) [13] working in Brazil noted that semi intensive pond culture of tilapia was typically integrated with agricultural or animal husbandry activities because pond fertilization with organic fertilizers promotes natural pond productivity in addition to being consumed directly by tilapia.

A relatively large percentage of ESP farmers (1.6 and 42.7 %) in Kiambu and Machakos counties practiced extensive fish production where ponds are fertilized using plant remains and animal droppings and fish fed on cereal by products such as maize and wheat meal with some fish meal. Kaliba *et al.,* (2006) [9] observed that in extensive fish production systems in Tanzania fish were fed on rice and maize bran, kitchen left overs and garden remains. Very few farmers practiced intensive fish farming system where pond fertilization and fish feeding are done using inorganic commercial fertilizers and formulated fish feeds respectively.

Table 15: Fish production systems in Kiambu and Machakos counties

Kiambu County				
	ESP		**Self-funded**	
Production level	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Extensive	2	1.6	2	9.1
Intensive	0	0	0	0
Semi-intensive	126	98.4	20	90.9
Total	128	100	22	100
Machakos County				
	ESP		**Self-funded**	
Production level	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Extensive	32	42.7	2	8.0
Intensive	8	10.6	0	0
Semi-intensive	35	46.7	23	92.0
Total	75	100	25	100

ESP- Economic Stimulus Program

O. Pond filling

Most of the ponds in these two counties were located in valleys due to closeness to the water source mainly rivers, wells and boreholes. Most ponds in Kiambu county (52 percent) were filled by gravity where furrows were dug from the water source mainly a river and water was directed to the pond. The remaining 48 percent of the farmers pumped water to fill their ponds which increased the cost of production due to the high cost of fuel. In Machakos County methods such as ferrying water using donkey were also grouped under pumping.

Rivers formed the greater percentage of water sources in Kiambu county because there are more permanent rivers and streams than in Machakos county. Fish farmers in Machakos county used different sources of water such as shallow wells (35 percent), borehole (30 percent) and rivers (27 percent) (Table XVI). It was therefore expensive and tedious to fill ponds in Machakos than in Kiambu. This study further showed that over 15 percent of ponds in Machakos County had dried which may imply that this region was not suitable for fish production. Results also showed that 89.6 percent of farmers in both counties did not experience any conflict in accessing water for filling the ponds while 10.4 percent experienced some conflict such as complaints of using a lot of water by neighbours located downstream. In Machakos County there were also fish farmers that drew a lot of water from the community boreholes.

Table 16: Sources of pond water

	Kiambu County		**Machakos County**	
Source of water	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Borehole	31	20.7	30	30
Well	11	7.3	35	35
River	93	62	27	27
Dam	3	2	4	4
Rain	10	6.7	4	4
Tapped	2	1.3	0	-
Total	150	100	100	100

P. Frequency of re-filling the fish ponds with water

The frequency of topping up pond water affected the quality of water in terms of turbidity and levels of dissolved oxygen. Majority of the fish farmers (67.2 percent) in Kiambu and (70.7 percent) in Machakos counties refilled their pond when water fell below a certain point, usually a point or level which was shown to them by government extension officers (Table XVII). This further showed the important role played by ESP which facilitated extension officers who trained farmers on pond management. The findings showed that self-funded farmers followed a similar regime of pond refilling. A small percentage 10.2 percent of the farmers in Kiambu county had continuous flow of water in their ponds due to availability of water. This is not a good management practice because it does not allow time for growth of phytoplankton which is the natural feed for the tilapia fish. The results were not significantly different between the two counties (p= 0.05) (Table IX). Isyagi *et al.,* (2009) [7] in a study in Uganda noted that water should only be added to top up water levels and to

correct water quality problems. The reduced frequency of pond refilling in Machakos County can be explained by the problem of water scarcity and seasonality of rivers.

Table 17: Frequency of refilling the fish pond with water in Kiambu and Machakos counties

Kiambu County				
	ESP		Self-funded	
Frequency of refilling	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Water falls below a certain point	86	67.2	12	54.5
Once a month	15	11.6	4	18.2
Once a week	8	6.3	2	9.1
Continuously	13	10.2	-	-
After 3 weeks	2	1.6	-	-
After 5 months	0	0	2	9.1
Twice a month	4	3.1	2	9.1
Total	128	100	22	100
Machakos County				
	ESP		Self-funded	
Frequency of refilling	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Water falls below a certain point	53	70.7	18	72.0
Once a month	5	6.7	2	8.0
Once a week	14	18.7	5	20.0
Continuously	1	1.3	-	-
After 3 weeks	-	-	-	-
After 5 months	1	1.3	-	-
Twice a month	1	1.3	-	-
Total	75	100	25	100

ESP- Economic Stimulus Program

Q. Pond draining

Pond draining is also an important aspect of pond management in that it influences the quality of water in terms of dissolved oxygen, fish health and primary productivity of the pond (Ngugi *et al*., 2007). Draining should be done at the end of each production cycle to get rid of accumulated chemicals which may be toxic to the fish. Majority of the farmers (86 percent and 65 percent in Kiambu and Machakos, respectively) did not drain their pond at all (Table XVIII). This is not good because leaving the pond water for too long without draining increases organic wastes which decreases the amount of dissolved oxygen which can lead to death of the fish.

Isyagi *et al.,* (2009) [7] noted that the accumulation of wastes can be physically managed by removing a proportion of the pond water with high nutrient load and replacing it with good quality water. A relatively large percentage (10.7 and 26%) in Kiambu and Machakos counties respectively drained their ponds once and this was usually during harvesting for farmers who did complete harvesting. Balance should be found in pond draining because draining of the pond too often allows no time for phytoplankton to grow which is the natural feed for the fish. It also causes fluctuations in water temperature which is not good for the fish.

Table 18: Frequency of pond draining

	Kiambu County		Machakos County	
Frequency of pond draining	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Never drained	129	86	65	65
Once	16	10.7	26	26
Twice	2	1.3	4	4
After 4 months	3	2	5	5
Total	150	100	100	1f00

R. Pond fertilization

Farmers in both Kiambu and Machakos counties used farm yard manure for pond fertilization with only few farmers using both manure and chemical fertilizers. The chemical fertilizer used was mainly diammonium phosphate (DAP) and it was used once during first stocking. Majority of the farmers in Machakos County (59 percent) had only fertilized their ponds only once since the pond was established (XIX). These ponds had poor water colour indicating that there was no primary productivity of algae. These findings are consistent with results by Diana and Lin (1998) [3], who reported that in ponds that were fertilized once tilapia had low growth rates in Thailand. In these ponds, nutrients were quickly utilized and primary production and growth rates of fish declined dramatically. Farmers in Kiambu county fertilized their pond more frequently compared to those in Machakos county. Consequently, 90 percent of ponds in Kiambu county had green water due to proper fertility management. The manure used was mainly from cattle, poultry and pigs showing a high level of integration between fish farming and other enterprises on the farm.

Farmers lacked information on when to add manure to their ponds because the decision to fertilize the pond should be informed by the colour of pond water. The frequency of fertilization is very important in pond management because fertilization enhances the primary productivity of the pond which positively influences fish growth. However, Knud-Hansen and others noted that fertilization frequencies varying from daily to once every three weeks had no effect on primary productivity of the pond (Knud-Hansen *et al*., 1993) [11].

These findings agree with results by Nhan *et al.,* (2007) [17] who noted that farmers used on-farm resources to produce fish and reduce environmental impacts of farming activity. They however lacked information on when to add manure to their ponds.

Table 19: Frequency of pond fertilization in Kiambu and Machakos counties

	Kiambu County		Machakos County	
Frequency of pond fertilization	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Only once since pond was established	46	30.7	59	59
Once a month	60	40.0	28	28
After 3 months	9	6.0	0	0
Twice a month	32	21.3	13	13
After 2 months	3	2.0	0	0
Total	150	100	100	100

S. Challenges in fish farming

The main challenge as reported by fish farmers was predators (41.3 percent and 39 percent of farmers in Kiambu and Machakos counties, respectively) (Table XX). Shitote *et al*., 2013 [21] reported predation was a major challenge in Western Kenya. Lack of feeds was not a major challenge in the two counties because most the fish feeds were provided by the government through the ESP. However, farmers reported high mortality of fingerlings due to lack of oxygen during the first few hours of stocking and delay in delivery of fingerlings as challenges which they experienced (Shitote *et al*., 2013) [21]. The problem of scarcity of water was experienced by 41% of farmers in Machakos County and 2 percent in Kiambu County mainly in Lari constituency which the driest part of Kiambu. In a study in Kisumu and Homa Bay counties, Jacobi (2013) [8] reported similar findings where the main challenges in fish farming were predators, water scarcity, marketing and poor management.

Only 19.2 percent of respondents had not experienced the problem of predators on their fish farms. Kingfisher was the main predator bird reported by 68.4 percent of farmers while 10 percent reported that vultures were the main predator. Frogs also formed 2 percent of total cases of predators where they created competition for feed with the fish leading to stunted growth of the fish. Farmers employed different methods of controlling predators including use of screen nets, scarecrows and using strings and wires strung across the pond to prevent the birds from diving into the water to get fish.

Table 20: Challenges faced by fish farmers in Kiambu and Machakos counties

	Kiambu County		Machakos County	
Type of challenge	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Predators	62	41.3	39	39
Lack of feeds	9	6	0	-
High mortality of fingerlings	34	22.7	20	20
Pond leakage	12	8	0	-
Scarcity of water	3	2	41	41
Lack of management information	22	14.7	0	-
Delay in delivery of fingerlings	8	3.2	0	-
Total	150	100	100	100

4. Conclusions and Recommendations

Majority of the respondents in Kiambu and Machakos County were self-employed in agriculture, while the rest were self employed in non-farm enterprise such as formal employment, domestic work and casual labour in Kiambu County. Machakos County had similar trends having 46 percent self employed in non-farm enterprise. Fish farming was practiced by a relatively large proportion of farmers below 50 years. The average land size was 2.5±3.47 and 4.27±4.78 acres in Kiambu and Machakos Counties respectively. Of the 250 respondents interviewed, 85.3% and 75% in Kiambu and Machakos counties respectively were recruited through the ESP. The main source of information on fish farming was government extension agents. Stocking of Nile tilapia in mixed sex monoculture was the most dorminant culture method and fish were mainly stocked in earth ponds. Majority of the fish farmers (67.2%) in Kiambu and (70.7%) in Machakos County refilled their pond when water fell below a certain point. The study showed that there was mixed fish farming and crop farming where water from the ponds was used for watering vegetable plots. The main challenge as reported by fish farmers was predators.

Currently, there are efforts to promote fish farming by the Kenyan Government through the revival of hatcheries, provision of fingerlings and extension support to farmers and linkage to markets. However, Policy makers need to include provision for credit to purchase pond liners and screen nets to control predation in future funding programs, In order to maximize production, there is need to develop basic understanding of nutrient dynamics, specifically the role of fertilization and natural productivity. Such under-standing will allow us to ensure that cost-effective diets are developed that take into account nutritional requirement, differences between species, natural productivity of the water bodies and the location-specific availability of inputs. Feeding rates or ration size need to be determined by pond and lastly, There is need for progressive documentation and profiling of case studies, lessons and success stories for knowledge sharing and propagation of best practices across the country.

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