Economic and Risk Analysis of Tilapia Production in Kenya

Tenth Work Plan, Marketing and Economic Analysis Research 4 (10MEAR4)
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Abstract

Fish farming in Kenya has potential to further develop commercial production of tilapia. Further growth and development of the tilapia industry in Kenya will depend upon its profitability and the effect of associated risks. Data from pond experiments, on-farm trials, and farm surveys were used to develop enterprise budgets and a risk analysis for two mixed-sex tilapia monoculture production scenarios: 1) stocking tilapia at 2/m^2 fed with rice bran; and 2) stocking tilapia at 3/ m^2 fed with a pelleted diet. Net returns/ha were highest for the farms feeding pellets while lower net returns/ha were obtained by the rice-bran fed alternative. Profitability was affected by feed cost, survival, and farm size. The lower yields from the rice-bran feed scenario resulted in its greater sensitivity to fluctuating survival and costs.

Introduction

Fish farming in Kenya dates back to the 1920s. Historically, it has been carried out by rural small-scale farmers in earthen freshwater ponds less than 300 m^2 as a supplement to traditional agricultural crops (Coche et al., 1994; Mbugua, 2002). In 2001, there were 7,688 fish farmers in Kenya with 16,244 ponds with a total area of 240 ha (Fisheries Department, 2000). Aquaculture contributed approximately 0.7% of the total annual fish supply in Kenya from 1980-1998. Nearly all (98%) of the total supply of fish in Kenya was freshwater fish.

Tilapia (*Oreochromis niloticus,Tilapia zilii*) is the principal fish raised in Kenya, but some farmers polyculture tilapia with *Clarias gariepinus* Fish production has been extensive, relying primarily upon organic or inorganic fertilizer as nutrients to produce yields that range from 0.05 to 0.15 kg/m^2/year. Some farmers supplement pond productivity by feeding rice, maize, wheat bran, vegetables, and fruit leaves. Supplemental feeding in these systems increases yields to between 0.5 and 1.5 kg/m^2/year (Mbugua, 2002).

Most of the fish produced is either consumed directly, bartered, or sold locally as a cash crop. Kenya has weather conditions, water, and land resources for greater aquaculture development (Mbugua, 2002). However, fish farming in Kenya, as in many other countries, has focused on production with little attention to economics (Tacon, 1987). The low aquaculture yields in Kenya are attributed to various management problems such as the lack of record keeping, inadequate knowledge of fish farming, lack of capital and financial assistance, an inadequate supply of quality seedstock, and a lack of affordable quality feed (Mbugua, 2002).

The Aquaculture Collaborative Research Support Program (PD/A CRSP) is one of a family of agricultural research programs partially funded by the United States Agency for International Development (USAID), which focuses on improving the efficiency of aquaculture systems. Research conducted by these programs helps farmers improve incomes and alleviate hunger without depleting the natural resource base on which they depend for food, fuel, fiber, and shelter. Since 1982 this CRSP has brought together resources of developing countries (Honduras, Indonesia, Panama, the Philippines and Rwanda until the 1994 war) and U.S. institutions to increase the efficiency of pond culture systems and to disseminate successful aquaculture strategies. New sites were established in Kenya and Peru in 1996 and in Mexico in 1998.

The Aquaculture CRSP activities in Kenya were designed to stimulate development of viable small-scale aquaculture business. The overall goal of this project was to develop enterprise budgets and business plans for farmers, policy makers, lending agencies, and prospective investors in Kenya. There appeared to be potential for Kenya to develop a larger commercial aquaculture sector, but fundamental budgets and economic information were needed for this sector to grow.

Research conducted by the Aquaculture CRSP at Sagana Fish Farm in Kenya has identified alternative management practices and technologies that may be suitable in the region. On-farm testing was a logical step in transferring research-based technologies to the farm and allows farmers to assess costs and benefits under local conditions as well as receive training in basic pond management skills. Project personnel trained fisheries extension officers through on-farm testing to complement formal classroom training.

The primary objective of this study was to analyze the profitability and risk associated with small-scale, commercial tilapia farming in Kenya. Specifically, enterprise budgets were developed for farm situations and management options judged to have potential for use on a small, but commercial scale. Results of this analysis provide guidelines for tilapia farmers to adjust to the changing conditions of tilapia culture in Kenya

METHODS AND MATERIALS

Data were obtained from a variety of sources to develop both the enterprise budgets and the risk analysis. Veverica et al. (2002) reported results of on-farm trials conducted on 52 ponds at a variety of management intensity levels and stocking combinations. Experimental data from Liti et al. (2001) and Veverica et al. (2000) provided more formal comparisons of the effects on production characteristics resulting from tilapia fed either rice bran or pig finisher pellets. Surveys conducted in 2003 (Munala, 2003; Enos, 2003) provided information on tilapia farm characteristics and input quantities and prices (Table 1). In addition, direct personal interviews were conducted of 16 tilapia farmers in Kenya in 2004 to corroborate price data and current production practices.

A representative enterprise budget was developed using standard budgeting techniques (Kay & Edwards, 1999). The base scenario was a 1-ha fish farm. The survey data showed that the land area owned by Kenyans raising tilapia averaged about 3 ha. While this land was used to grow livestock, tea, sugar cane and other grain and vegetable crops, it was assumed that a portion of this land would be available for tilapia production. Average farms had two ponds per farm with an average pond size of 310 m^2. Initial budget simulations revealed that fish farming areas less than 1 ha were too small to cover all costs of production; thus, the base budget was assumed to be 1 ha. Additional sensitivities were run to identify the sources of economies of scale and factors that caused farms less than 1 ha to be unprofitable.

Farmers raised tilapia (*Oreochromis niloticus*) in monoculture or in polyculture with clarias (*Clarias gariepinus*). Farmers harvested ponds twice a year on average, with partial harvests as needed to restock ponds. The base scenario used in the budget analysis was that of mixed sex tilapia monoculture. While clarias is raised on some farms, tilapia production was the most common form of production. Veverica et al. (2002) demonstrated that tilapia monoculture had greater profit potential as a commercial business venture and that the more common tilapia-clarias production system was more suitable for small-scale, near-subsistence farming.

Enterprise budgets were developed both for a production system based on stocking tilapia at a rate of $2/m^2$ and fed with rice bran and a second system in which tilapia were stocked at $3/m^2$ and fed a pelleted diet. Assumed yields were 4,224 kg/ha/yr for the rice bran-fed system and 10, 464 kg/ha/yr for the pelleted-fed production system. The studies used as the basis for this analysis showed wide ranges of tilapia yields. This is primarily due to the wide variety and dynamic nature of tilapia farming in Kenya. The yields for this analysis were developed based on a spreadsheet-based simulation of production by pond. A key assumption was that, in order to operate on a commercial basis, the farm would need to supply markets on a year-round basis. To do so would require staggering stocking and harvesting throughout the year. Thus, the model was built by stocking two ponds at a time so that marketable fish would be available throughout the year. The sum of the stocking and harvesting events resulted in the yields reported above. The resulting yields are consistent with those obtained in both experimental and farm trials under similar production conditions.

Tilapia price assumed in the budget was US$ 1.32/kg, based on information collected in 2004. Commercial size of tilapia varied between 200 and 350 g per fish and the most common product form sold was whole-dressed, fresh tilapia.

In Kenya revenue from tilapia production represented 20% of the total farm income, on average (Munala, 2004). Income generated from fish farming was re-invested in fish culture, used for other agricultural activities, spent for school fees for children, allocated to household goods, and budgeted to meet other needs such as paying taxes, purchasing medication, and buying hillside land and livestock.

Survey data showed that farmers purchased fingerlings typically from either a government fish station or another private producer to stock ponds (Munala, 2003; Enos, 2003). The average price of tilapia fingerlings was

$0.03 (USD). Many of the Kenyan tilapia farmers used agricultural byproducts to feed fish and fertilize ponds. Record-keeping of quantities fed and fertilized was minimal and many farms used inputs as they were available with little consistency over time. Commercial feed was purchased when cash was available but byproducts were used otherwise.

Most of the farmers surveyed raised a variety of crops and did not spend all their time and labor on fish production. Family labor was allocated across the various crops. Farmers typically spent approximately one hour at the ponds for the two daily feedings and to check on the fish and the ponds. Labor time in the budget included: adding water to ponds, plugging leaks in the levees, pulling weeds, cutting grass, applying feed and manure, and watching the ponds.

Fixed costs in fish farming include the cost of constructing ponds and equipment. Fish ponds in Kenya are constructed by hand, often exclusively with family labor. Pond construction costs reported by farmers averaged $0.9/m^2. The Munala survey (2003) showed that Kenyan farmers do not have much equipment. A seine cost between $26 and $66. In addition, most farmers owned some baskets, a shovel, a hoe, a scale, and a ruler.

Credit is not readily accessible for Kenyan farmers and information on loans is difficult to obtain. Lenders require a good credit history and substantial collateral. Farm land owned was most commonly used as collateral at a rate of 2.5 times the value of the loan. Cattle, poultry, or other properties were occasionally also used as collateral. Annual interest rates imposed by bank lenders and Non-Governmental Organizations (NGOs) can vary from 10% to 85% with a term of 5 years. Given that several lenders and governmental agencies expressed interest in providing assistance and fairly favorable credit terms for aquaculture, an annual interest rate of 12% was used initially for this analysis.

The effect of risk on profitability was evaluated by incorporating production variability in the enterprise budgets and conducting repeated Monte Carlo simulations. The risk analysis was conducted as a stochastic simulation using Crystal Ball™ software (Decisioneering, Inc., Denver, Colorado), a spreadsheet add-on program to Microsoft EXCEL® that allows the incorporation of uncertainty in risk analysis models. This program has been used previously for bio-economic modeling of aquaculture firms (Valderrama and Engle, 2001; Zucker and Anderson, 1999). Monte Carlo simulation techniques (500 iterations per simulation) were used to generate values for individual cost and quantity items based on the probability distributions. Results include the entire range of possible outcomes for parameters such as gross receipts, total costs, and net returns, as well as their associated probability.

Probability distributions for random variable budget components were selected based on availability of data and with input from professionals familiar with tilapia farming in Kenya. Table 2 summarizes the choice of distributions for each random variable included in the risk analysis and the corresponding distribution-parameter values. Production area (ha) within each farm category was defined with a uniform distribution: all values between the minimum and maximum occur with equal likelihood, and minimum and maximum values correspond to the limits for each size range. A normal distribution was used to define the feed conversion ratio of tilapia. This parameter is determined by the type of feed, metabolism, and by weather patterns that fluctuate randomly.

Survival rate, farm prices and production cost were described by triangular distributions based on the most likely value (means included in the enterprise budgets) and minimum and maximum values determined from the original data for each scenario. Triangular distributions were selected for this analysis given the low number of observations available for each farm scenario. Triangular distributions are considered to provide the best representation of estimates when only a small number of data can be obtained (Taha, 1988). Tilapia price depends on average tilapia size, marketing strategies, and supply-demand interactions with the wild-caught tilapia likely supplied from Lake Victoria and other impoundments at the moment of harvest. Crystal Ball™ generated random numbers for each cell independently of the values used for others.

The likelihood of achieving profit (positive net returns) and the distribution of outcomes for total revenue, total costs, breakeven yield, breakeven price, and the probability of losses were calculated for each farm scenario. The Monte Carlo simulations conducted with Crystal Ball™ generated probability distributions for the recalculated FCR, survival rate, tilapia price, fingerling cost, and feed price, for each farm scenario.

RESULTS AND DISCUSSION

Enterprise Budget for Farms Feeding With Rice Bran

Table 3 presents the enterprise budget for a 1-ha mixed-sex tilapia monoculture operation that stocked tilapia fingerlings at 2/m^2 in fertilized ponds and fed rice bran. This farm was assumed to produce 4,224 kg of live tilapia per year. At an average price of US $1.32/kg (2004 average exchange rate: US$1:76 Kenyan shillings), this level of production generated $5,576 in total revenue. Total variable costs (TVC) were $4,146 of which feed (25% of TVC), fingerlings (19% of TVC), labor (14% of TVC) and security personnel (17% of TVC) were the most important. As the fish farm intensified in terms of increased stocking density, natural foods in the pond, even when enriched by fertilizers, is not enough to satisfy the nutritional requirements of the fish. Thus, supplemental feeds become necessary. Total fixed costs were $730 and represented only 15% of the total cost of production. Net returns/ha were $700; the breakeven price and yield above total costs were $1.15/kg and 3,694 kg/ha/year, respectively. Thus, tilapia farming in Kenya, stocking at 2 fingerlings/m^2 and feeding with rice bran on a 1-ha farm, was profitable.

Previous studies in Rwanda showed, in an annual enterprise budget for fish production in a 100m^2 fishpond, the total fixed cost to be 58% of the total cost (Hishamunda et al., 1998). However, the Rwandan analysis was limited to subsistence farming practices in which cash was not available for purchasing feed and labor; thus, these costs were not considered.

Enterprise Budget for Farms Feeding With Pig Finisher Pellets

The higher stocking rates of 3 fish/m^2, combined with a higher quality, pelleted feed resulted in higher yields of 10,464 kg of live tilapia per year (Table 4). At an average price of US $1.32/kg, this level of production generated $13,812 total revenue. Total variable costs (TVC) were $9,981 of which the major cost was for feed (56%), followed by tilapia fingerlings (14%), interest on operating capital (11%), and security personnel (7%). The higher stocking rates required a more complete diet as well as increased quantities of fish feed. The pelleted diet required higher levels of TVC, but also resulted in high yields of tilapia. Total annual fixed costs were $730 and represented 7% of the total cost of production. Total production cost/ha reached $10,712, which is higher than the costs/ha reported by the rice bran scenario. However, superior pond yields compensated for the additional production costs incurred by these farms. Net returns/ha were $3,101; the breakeven price and yield above total costs were $1.02/kg and 8,115 kg/ha/year, respectively. Net returns from a farm fed with formulated feed doubled the net returns when compared with farms fed with rice bran. This is due primarily to higher yields that result from higher growth rates due to the improved feed conversion ratio. Formulated feed diets ensure optimal digestibility and growth of fish.

Fish feeds constitute the major proportion of the operating costs in both intensive and semi-intensive culture systems globally. Feed costs for feeding tilapia with rice bran were 25% of the variable cost while for a farm feeding with formulated feed were 56%. The production time for a batch of tilapia fed the pelleted diet was shorter (9 months) than that for tilapia fed rice bran (11 months) because the growth rate was higher with pellets and fish reached market size more quickly. For a farm feeding rice bran, 24 ponds would be needed to have market-sized fish available for weekly harvests, while only 20 ponds would be needed by farms feeding a formulated feed due to the shorter length of time to reach market size.

Sensitivity Analysis

Sensitivity analyses were carried out that described the variations in net returns and breakeven prices as a consequence of variations in feed cost, survival, and farm size for both scenarios. Net returns were sensitive to changes in feed prices (Fig. 1). Feed prices were increased in increments of $0.05/kg in four successive increments. As feed prices increased, net returns decreased and breakeven price increased. Increases in the cost of rice bran affected net returns more than did changes in the cost of pelleted diets. Production of tilapia fed rice bran became negative with a $0.05/kg increase in the price of rice bran whereas the cost of pelleted feed had to increase to $0.15/kg before net returns/ha became negative. The rate of decrease in net returns/ha was greater for the rice bran scenario than for the pelleted feed scenario. Breakeven prices increased in a similar fashion.

As survival decreased, net returns decreased, and breakeven prices increased (Fig. 2). The rice bran-fed scenarios demonstrated greater sensitivity to varying survival rates than those scenarios that were fed pelleted feeds. Survival rates below 90% were not profitable for either scenario.

Increasing farm size up to 3 ha in size resulted in lower breakeven prices and higher net returns (Fig. 3). Neither scenario was profitable at a farm size smaller than 1 ha.

Risk Analysis

Risks in tilapia farming result from fluctuation in variables such as yield and prices that, in turn, create fluctuation in breakeven prices, yield and net returns. Relatively little variation was found for tilapia prices, even between rainy season and dry seasons when most tilapia sold in the markets is wild caught from Lake Victoria. In contrast, variations in yield were encountered due to stocking densities, quality of feed, and survival rates.

Figure 4 presents the probability distribution of net returns for the rice bran-fed tilapia farm. The likelihood of achieving profit was 83%, while the corresponding certainty level was 99% for the farm fed a pelleted diet (Fig. 5). Overlay charts in Figures 6, 7, and 8 superimpose the reverse cumulative distributions corresponding to the forecasts for each farm scenario. The distribution of gross receipts for the farm feeding with pellets was dominant over the farm scenario feeding with rice bran (Fig. 6). Thus, for any given revenue value, the probability of observing higher values is larger for the farmers feeding their fish with pellets. Similarly, total farm cost and net returns were likely to be higher for farms feeding with pellets (Fig. 7–8). The distributions of breakeven prices followed different patterns across scenarios (Fig.

9). Thus, for any given quantity of tilapia sold, the probability of observing higher values is larger for the farmers feeding with rice bran. Higher yields characteristic of farms feeding with pellets resulted in the narrowest distribution of breakeven prices. Breakeven yields also were larger for farmers feeding with pelleted diets. Low total production costs/ha caused farms feeding with pellets to have the narrowest distribution of breakeven prices.

Implication for Management

Net returns is the most common criterion under which management decisions are evaluated in business enterprises. Nevertheless, net returns are rarely known with certainty, but are often associated with a distribution of possible outcomes that may include the potential for loss (Hatch et al., 1987). Strategies, targeted to achieve large profits, commonly also entail greater probabilities of losses. For highly risk averse individuals, these higher profit alternatives may look less attractive than conservative choices associated with a narrower distribution of returns and a reduced potential for loss. The decision depends ultimately on the owner's income risk preferences. However results of this analysis indicated that farm managers who adopted a more intensive technology level (formulated feed) in 2004 obtained larger crops and a wider profit margin than those who operated with non-pelleted rice bran.

The risk analysis was intended to capture the variability of input and output factors in the production of farm-raised tilapia in Kenya under different feeding management scenarios. Results were influenced strongly by variations in factors such as feed cost, survival, and farm size.

Anticipated Benefits

This analysis provides enterprise budgets for two tilapia production scenarios for potential as commercial business ventures in Kenya. Break-even survivals, feed prices, and tilapia prices were identified. Capital requirements for both investment and operating capital were identified. These analyses should provide a basis for farmers and lenders to begin to evaluate the economic feasibility of tilapia farming business ventures.

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Table 1. Selected tilapia farm characteristics and input quantities and prices, Kenya, 2004.

Average from Kenyan farms	Sources			
	Unit	*Mulana*[a]	*Enos*[b]	*Total*
Farms	#	76	22	98
Land size	Ha	3	3	3
Pond area as % of farm area	%	2	2	2
Number of ponds	#	2	3	2
Area of ponds	m^2	263	473	310
Cost of ponds	US$/$m^2$	1.0	0.4	0.89
Revenue				
Total fish sales	US$	122	554.9	220
% of farm income from fish sales	%	18	26.2	20
Price per fingerling sold	US$	0.05		0.05
Total value of fingerlings sold	US$	43		43
Fingerling stocking				
Number of fingerlings	Individual	392		392
Cost of fingerlings	US$/Individual	0.03		0.03
Fertilizer and feeds				
Cattle manure	Kg	1,046		1,046
Chicken manure	Kg	762		762
Other fertilizer	Kg	1,169		1,169
Maize bran	Kg	542		542
Slaughter waste	Kg	880		880
Kitchen waste	Kg	404		404
Fresh vegetables	Kg	423		423
Growers mash	Kg	442		442
Other feeds	Kg	739		739
Maize bran	US$	185		185
Slaughter waste	US$	30		30
Kitchen waste	US$	30		30
Fresh vegetables	US$	131		131
Growers mash	US$	65		65
Other	US$	4,392		4,392
Commercial feed	US$		5,242	5,242
Agric by-products feed	US$		1,782	1,782
AgFeed/m^2 feed	US$		4	4
Natural feed	US$		654	654
Urea	US$		789	789
DAP	US$		779	779
Organic fertilizer	US$		267	267

[a]Munala (2004).
[b]Enos (2004).

Table 2. Selected assumptions for the risk analysis of tilapia in Kenya. Parameter distributions are given for each variable and scenario. Estimates are based on production data from Veverica et al. (2002), Munala (2003), Enos (2003). Triangular distributions were used for all variables.

Variable	Unit	Distribution	Parameters	Farms feeding rice bran	Farms feeding pellets
FCR	ratio	normal	minimum	4.19	2.74
			maximum	6.05	4.18
			mean	5.12	3.46
			standard deviation	0.31	0.24
Survival	%	triangular	minimum	70	70
			maximum	95	95
			likeliest	90	90
Tilapia price	dollars (U.S.)	triangular	minimum	1.05	1.05
			maximum	1.58	1.58
			likeliest	1.32	1.32
Fingerling cost	dollars (U.S.)	triangular	minimum	0	0
			maximum	0.07	0.07
			likeliest	0.04	0.04
Feed price	dollars (U.S.)	triangular	minimum	0.03	0.1
			maximum	0.07	0.18
			likeliest	0.05	0.16

Table 3. Annual enterprise budget for a 1-ha tilapia farm fed rice bran, stocked at 2 tilapia/m^2, Kenya. ($1.00 (U.S.) = 75 Kenyan shillings).

Item	Unit	Quantity	Price	Total
Gross returns				
Tilapia, live whole-dressed, 234 g	kg	4,224	1.32	5,576
Total gross receipts				5,576
Variable costs				
Fingerlings, 5 g each	each	19,968	0.04	799
Rice bran	kg	20,592	0.05	1,030
Fertilizer				
Urea	kg	528	0.26	137
Diammonium phosphate	kg	252	0.29	73
Agricultural lime	kg	2,500	0.05	125
Labor (stock, feed, fertilize,harvest)	$	365	1.58	577
Pond management (levee repairs)	$	152	1.58	240
Security personnel	$	365	1.98	721
Interest on operating capital	$	3,701	12%	444
Total variable costs	$			4,146
Income above variable costs	$			1,430
Fixed costs				
Depreciation				
Equipment	$			118
Ponds	$			237
Interest on investment	$			375
Total fixed costs	$			730
Total costs	$			4,876
Net returns to management	$			700
Net returns to management	$/ha			700
Breakeven price				
above total variable costs	$/kg			0.98
above total costs	$/kg			1.15
Breakeven yield				
above total variable costs	kg/ha/yr			3,141
above total costs	kg/ha/yr			3,694

Table 4. Annual enterprise budget for a 1-ha tilapia farm fed pellets, stocked at 3 tilapia/m^2, Kenya. ($1.00 (U.S.) = 75 Kenyan shillings).

Item	Unit	Quantity	Price	Total
Gross returns				
Tilapia, live whole-dressed, 234 g	kg	10,464	1.32	13,812
Total gross receipts				13,812
Variable costs				
Fingerlings, 5 g each	each	36,000	0.02	1,440
Pelleted	kg	34,992	0.2	5,599
Fertilizer				
Urea	kg	528		137
Diammonium phosphate	kg	252		73
Agricultural lime	kg	2,500	0.05	125
Labor (stock, feed, fertilize,harvest)	$	365	2	577
Pond management (levee repairs)	$	152	2	240
Security personnel	$	365	2	721
Interest on operating capital	$	8,912	12%	1,069
Total variable costs	$			9,981
Income above variable costs	$			3,831
Fixed costs				
Depreciation				
Equipment	$			118
Ponds	$			237
Interest on investment	$			375
Total fixed costs	$			730
Total costs	$			10,712
Net returns to management	$			3,831
Net returns to management	$/ha			3,101
Breakeven price				
above total variable costs	$/kg			0.95
above total costs	$/kg			1.02
Breakeven yield				
above total variable costs	kg/ha/yr			7,562
above total costs	kg/ha/yr			8,115

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