ON-FARM TRIALS: EVALUATION OF ALTERNATIVE AQUACULTURE TECHNOLOGIES BY LOCAL FARMERS IN KENYA

Ninth Work Plan, Appropriate Technology Research 1 (9ATR1)
Progress Report

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ABSTRACT

Research conducted by the PD/A CRSP at Sagana Fish Farm has begun to identify alternative management practices and technologies that may be suitable in the region, but it should not be assumed that results obtained under controlled experimental conditions at Sagana are directly transferable to farms in the area. On-farm testing is therefore a logical step in transferring research-based technologies to the farm. On-farm testing of various alternatives allows farmers to assess their costs and benefits under local conditions as well as to receive instruction and training in basic pond management skills. Such trials also allow project personnel to work with and train the fisheries extension officers who are involved in the trials at the various locations, thus complementing the training they receive through "regular" training activities.

Thirty farmers were selected to participate in on-farm trials in four districts of Central Province and one district of Eastern Province, Kenya, in 1999 and 2000. A pre-trial workshop including farmers, extension agents, Kenyan and US CRSP personnel, and students working on research projects at Sagana was held in December 1999 to discuss and select management schemes for testing, to agree on how the trials would be conducted, and to plan for proper record keeping during the trial period. Fifty-two ponds were stocked with monosex male tilapia (*Oreochromis niloticus*), mixed-sex tilapia, and/or catfish (*Clarias gariepinus*) between January and March 2000. Stocking densities were 2 fish m^{-2} for tilapia, 0.2 fish m^{-2} for catfish stocked with tilapia, and 1 fish m^{-2} for catfish stocked alone. Management schemes tested included high, medium, and low management levels. Ponds were sampled for fish growth at four- to six-week intervals, and farmers kept records of input type and weight, input costs, pond water additions, fish mortality, and fish sampling data. A post-trial workshop was held in March 2001 to summarize and evaluate the results of the trials. As a result of their participation in these trials, farmers learned that improved management can indeed lead to increased production, something that they were not convinced of prior to the trials. The average increase in fish harvested during these trials was 330% (3.5 t ha^{-1}, as compared with an estimate of just over 1 t ha^{-1} prior to the trials). Almost two-thirds of the ponds gave net revenues exceeding KSh 250,000 ha^{-1} yr^{-1}; the average was KSh 310,832 ha^{-1} yr^{-1}. Farmers also concluded that increasing the size of their ponds would further contribute to increases in production.

Phase two of the trials—in the western region of Kenya—began with a visit to the six districts' headquarters in December 2000. In May 2001, a pre-trial farmers workshop was held at the Bungoma Farmers Training Center to discuss and select management options suitable to the farmers. Ponds for the western region trials were stocked in May and June, and the first sampling visits were conducted in August. The trials are ongoing as of this report. As in the Central and Eastern Provinces, a post-trial workshop will be held to evaluate the results of these trials.

INTRODUCTION

Fish farmers throughout Kenya, as well as the extension agents who serve them, have suffered from a lack of information about good pond management practices and technology alternatives that may be available to them. Some of the major consequences of this are that many current farmers do not achieve good fish production in their ponds, other farmers become "inactive," and potential farmers avoid going into fish culture because its profitability has not been demonstrated to them. These and other factors have typically combined to result in low productivity from Kenyan fish ponds.

Research conducted by the PD/A CRSP at Sagana Fish Farm has begun to identify alternative management practices and technologies that may be suitable in the region, but it should not be assumed that results obtained under controlled experimental conditions at Sagana are directly transferable to farms in the area. On-farm testing is therefore a logical step in transferring research-based technologies to the farm. On-farm testing of various alternatives allows farmers to assess their costs and benefits under local conditions as well as to receive instruction and training in basic pond management skills. Conducting such trials also provides opportunities for project personnel to work with and train the fisheries extension officers who are involved in the trials at the various locations, thus complementing the training they receive through the Kenya Project's training activity ("Aquaculture training for fisheries officers in Kenya," 9ADR3).

The specific objectives of this activity are to:

1) Collaborate with local fish farmers to test technologies developed through PD/A CRSP research at Sagana Fish Farm and elsewhere;
2) Demonstrate improved management techniques to extension officers and farmers; and
3) Teach simple methods for evaluating costs and benefits to farmers and extension agents.

This progress report mainly addresses on-farm trials conducted in the Central and Eastern Provinces during the period of 1999 to 2001. It also introduces the second phase of the trials, now being conducted in the western region of Kenya. A final report on the entire activity will be compiled when the western region trials are completed later this year.

METHODS AND MATERIALS

Preparatory contacts with farmers in Central Province and organizing activities were begun well before the beginning of this reporting year, but the pre-trial workshop and the beginning of the trials themselves were delayed. However, contacts with potential participants were maintained, and pond visits and surveys were made during the month of November 1999. Each fisheries officer was asked to interview farmers wishing to participate in the trials and select ponds based on the following criteria:

1) The owners are interested in participating in the trials.
2) Pond surface areas are 100 m^2 minimum and 1,000 m^2 maximum.
3) The ponds are drainable.
4) The average water depth of each pond is 80 ± 10 cm.
5) The pond is not prone to flooding.
6) Seepage from the pond is less than 10 cm per week.

For each district it was decided to select two focal points that, if possible, would be in areas having different climates or soil types. Each focal point had an extension agent assigned to it. By December 1999, 30 farmers with 52 ponds had been selected to participate, although some farmers needed to renovate some of their ponds prior to beginning the trials. A total of 20 fisheries officers and extension agents were also involved in the Central and Eastern on-farm trials.

Pre-Trial Workshop

A workshop to discuss pond management options and to make stocking and management plans for each farmer's ponds was conducted from 14 to 17 December 1999. Farmers, extension agents, CRSP personnel, and some of the students involved in thesis work at Sagana participated. Farmers elected to try either a "no cash expenditure" type of management, which relied on inputs such as manures and leaves found on their farm, or a "purchased feed/fertilizer" management scheme, which featured chemical fertilizer and a feed such as bran or maize germ. These options were based on the treatments proposed in the Ninth Work Plan, which were:

1) Monosex tilapia (*Oreochromis niloticus*) + catfish (*Clarias gariepinus*), with bran + inorganic fertilizer, based on most recent recommendations from Sagana Fish Farm;
2) Same as Treatment 1 except with mixed-sex tilapia;
3) Monosex tilapia and catfish, with weekly additions of manure or organics at 500 kg total solids (TS) ha^{-1} wk^{-1}; and
4) Same as Treatment 3, except with mixed-sex tilapia.

Many farmers had more than one pond and elected to try monosex tilapia in one pond and mixed-sex tilapia in another. Most farmers who stocked tilapia also stocked a small number of *Clarias* (about 10%). A few farmers opted for all *Clarias* (stocked at 1 m^{-2}) because they had access to meat scraps and manures.

Pond management and record-keeping techniques were also discussed at the pre-trial workshop. Considerable flexibility was allowed with respect to the management schemes that farmers chose to test, provided they agreed to keep good records of their efforts.

Trials

Ponds were stocked beginning 15 January 2000, using 10-g sex-reversed male or mixed-sex *O. niloticus*, depending on the treatment selected, and 5-g *C. gariepinus*. Stocking densities were 2 fish m^{-2} for *O. niloticus* and 0.2 fish m^{-2} for *C. gariepinus*. All fingerlings came from Sagana Fish Farm. Some farmers could not finish renovations in time, and stocking of their ponds had to be delayed until February or March. More than 12,500 tilapia fingerlings and 1,600 *Clarias* fingerlings were stocked.

Farmers were visited monthly by their extension agents and either monthly or every other month by their area fisheries officers accompanied by the extension agents. Sampling of ponds for fish growth was attempted with a four- to six-week frequency. Water chemistry parameters were not measured due to lack of personnel, high transport and per diem costs for fisheries officers, and the lack of electrical power at Sagana. Most travel money was used to pay for fisheries officers and extension agents to visit the farmers.

Visits were made by Judy Amadiva (Social Development Officer at Sagana Fish Farm), Enos Mac'Were (post-graduate student at Moi University), and Charles Ngugi to all farmers on three to five occasions during the trials. The fisheries officers often joined in the visits, especially in Kiambu and Embu, because they could get a ride with the Sagana staff. Nyeri fisheries officers had trouble in joining the visits because it was considerably out of the way for Sagana staff to pass by the Nyeri office on the way to and from the farmers' ponds. Although the CRSP vehicle was put at the disposal of the Kirinyaga officer when requested, requests were not made after the ponds were stocked. Extension agents were present for all of the visits at all of the sites except for those in Kirinyaga.

During the trials it became clear that the farmers who intended to purchase bran and fertilizer were having a difficult time because prices had soared. For example, a 40-kg bag of wheat bran that previously sold for KSh 200 to 400 was selling for KSh 800 in Embu. Farmers did not think that feeding bran was a good decision under this price regime. With an anticipated feed conversion ratio of 3 to 5 and a fish selling price of KSh 100 kg^{-1}, paying KSh 20 kg^{-1} wheat bran would not be advisable. So farmers were advised to switch to cassava leaves. Some of the farmers still purchased some chemical fertilizer, but others switched to manure as fertilizer. Therefore, instead of classifying the management levels of "cash vs. no-cash inputs," they were classified as high, medium, and low management. High management was defined as daily feeding of a high-value feedstuff like formulated animal feeds and slaughterhouse wastes. Medium-level management was characterized as consistent feeding (about 5 days a week), even if it was only leaves, and fertilizing every week or two. Ponds that received intermittent feeding and fertilization, with mostly manures and some leaves, were considered to have received low-level management. The management levels were assigned before harvest data were assembled, based on interviews and observations by Mac'Were and Amadiva.

Table 1. Responses obtained during the post-trial workshop to Question A: Were you satisfied with the extension services offered?

District	Yes	No	Not Sure	Total Farmers
Kiambu	4	0	1	5
Nyeri	5	0	0	5
Murang'a	3	0	2	5
Kirinyaga	1	2	1	4
Kiangwachi*	2	0	0	2
Embu	3	0	0	3
Total	**18**	**2**	**4**	**24**

* Two rice farmers who received advice from Sagana

Post-Trial Workshop

Farmers who had harvested their ponds were invited to the final meeting held on 5 and 6 April 2001. Some of those who had not yet harvested attended as well, bringing the total number of farmers present to 27. Extension agents and fisheries officers also attended. Most of the harvest information had been sent to Sagana earlier, but remaining questions were cleared up and all harvest data verified in interviews with farmers and extensionists conducted by Ngugi and Mac'Were. Geraldine Matolla and Amadiva interviewed farmers upon their arrival at the meeting using the questions in Tables 1 through 8 as a guide. Questions D and E (Tables 4 and 5) of the

Table 2. Responses obtained during the post-trial workshop to Question B: How can extension services be improved?

Suggested Improvements	Number of Responses	Percent of Farmers
Provide transport for extension agents	8	33
Better training of extension agents (more practical)	3	13
Extension agents need to make more regular visits to farmers	2	8
Extension agents should help the farmers with record keeping	1	4
Extension agents should try to encourage more people to farm fish	1	4
Farmers should be given printed technical information bulletins	1	4
Government should assist with distribution of fingerlings and inputs	1	4
Provide harvesting gear for extension agents	1	4
Total	**17**	

Table 3. Responses obtained during the post-trial workshop to Question C: What new management techniques did you learn?

New Techniques	Number of Responses	Percent of Farmers
Various options on feed types	13	59
Various options on fertilizer types (includes compost cribs)	10	45
Record keeping	7	32
Proper pond construction	5	23
Application rates for feeds and fertilizers	4	18
Adjusting stocking density to management level and desired fish size	3	14
Methods of predator control	3	14
Culturing a new species (catfish)	2	9
Integration of fish and livestock/poultry	2	9
Correct water management (static water)	1	5
Total	**50**	

interview were asked after the plenary session in which results were discussed. Answers were classed and tabulated by Veverica and Amadiva. Beatrice Nyandat and Susan Imende interviewed the extensionists.

After the first evening of the workshop, harvest data were compiled and sorted according to best yields (kg ha^{-1} yr^{-1}) and highest net revenue (KSh ha^{-1} yr^{-1}). The results were annualized to accommodate the different lengths of the production cycle practiced by the farmers. The results were presented to the farmers, and those who obtained the highest productions and the highest net revenues were invited to tell the group how they did it. Net revenues per pond were presented, and farmers noticed that the larger ponds had the highest net revenues. A table organized in order of highest to lowest net revenues per hectare was then presented and discussed.

Table 4. Responses obtained during the post-trial workshop to Question D: How did your results in the trial compare with your previous production results?

Response	Number of Responses
New Farmer	3
No Records/Can't Remember	3
Better	15
The Same	0
Worse	0
Total	**21**

Western and Rift Valley Province Trials

Trials in the western region began with a visit to the six districts' headquarters in December 2000. On 18 to 20 April 2001 we held a pre-trial farmers workshop at the Bungoma Farmers Training Center to discuss and select management options suitable to the farmers. Stocking dates, stocking densities, management levels, record keeping, and other issues were also agreed on at the meeting. In May and June 2001 Ngugi and Amadiva traveled to the districts and assisted with stocking on-farm trial ponds. Stocking information for the western region trials is summarized in Table 9. There are six fisheries officers and ten extension agents involved in this set of trials. Stocking densities used are the same as those used for the Central and Eastern trials. However, many of the farmers in the western trial are using a relatively high-quality feed consisting of fish meal, blood, and flour. This is expensive and

Table 5. Responses obtained during the post-trial workshop to Question E: What part of the harvest did you sell and what did you do with the revenues?

Response	Number of Responses	Percent of Farmers
Purchase more inputs for the pond	10	42
Used in general household/Institution budget	10	42
Paid school fees	5	21
Paid for pond renovation	2	8
Bought inputs for other farm enterprises	1	4
Paid medical/Purchased medicines for family	1	4
Total	**29**	

Table 6. Responses obtained during the post-trial workshop to Question F: Will you change your management? How?

Response	Number of Responses	Percent of Farmers
Will feed and fertilize at more regular intervals	15	68
Will use more inputs available on the farm	8	36
Will switch to fingerling production and sale	5	23
Will use some chemical fertilizer	4	18
Will construct more and better ponds	3	14
Will increase pond size	3	14
Will keep better records	2	9
Will renovate old ponds	2	9
Will sell some fish as well as consume at home	2	9
Will try harder to prevent predation	2	9
Will purchase "stockers" for quick grow-out	1	5
Will stop flowing water through pond	1	5
Will stop relying on extension service	1	5
Will switch to catfish culture	1	5
Will try carp culture	1	5
Total	**51**	

Table 7. Responses obtained during the post-trial workshop to Question G, Part 1: How many other people knew about these trials and about your participation in them?

District	Other Farmers	Family Members	School Kids, Parents, Teachers	Total	Number of Farmers Who Want to Begin	Number of Farmers Who Culture Fish	Number of Ponds Constructed
Kiambu	9	10	599	618	6	1	1
Nyeri	52	10	0	62	18	8	8
Murang'a	40	0	0	40	23	16	15
Kirinyaga	43	2	59	102	0	6	3
Kiangwachi*	10	0	0	10	10	0	0
Embu	48	0	60	108	5	0	1
Total	**202**	**22**	**718**	**942**	**62**	**31**	**28**

* Two rice farmers who received advice from Sagana

Table 8. Responses obtained during the post-trial workshop to Question G, Part 2: How many other people knew what farmers were doing with these trials—according to the Fisheries Officers?

District	Number Who Knew
Kiambu	> 400
Nyeri	> 500
Murang'a	> 300
Kirinyaga	0*
Embu	800–1,000
Total	**2,000–2,500**

* One agent privately said 300

farmers often stop feeding their fish if they do not have the money to purchase feed. Many were surprised to hear that other things on their farm could be used as feeds, and several of them decided to test farm by-products and compare results with those obtained using-high quality feed. As in Central and Eastern Provinces, a post-trial workshop will be held in December 2001 to evaluate the results of these trials.

RESULTS

Of the total 52 ponds stocked, 16 did not report any harvest data (Table 10). Some farmers combined data from more than one pond, so their total surface area was used to calculate yields and revenues, and management intensity was judged based on all the ponds. One group that combined mixed-sex and monosex pond data could not be included in the comparison of these two stocking strategies. The farmers, fisheries officers, and extension agents from the district of Nyeri are to be congratulated for complete reporting.

Some natural phenomena prevented harvest data collection. Some ponds dried up during the drought, and another farmer had his pond wash out after heavy rainfall. One farmer reported a total loss due to predation by otters. Thieves stole the fish from the prison ponds in Kiambu. Prison pond sampling data were used to calculate their pond productivity, but these ponds were not included in the economic analysis. Many of those reporting harvest had not yet drained their ponds, but they thought they had harvested the majority of the fish.

Table 9. Numbers of farmers participating and numbers of ponds stocked in districts and provinces of the western region for on-farm trials begun in 2001.

District	Province	Farmers	Ponds
Bungoma	Western	3	6
Busia	Western	4	6
Kakamega	Western	3	6
Trans Nzoia	Western	3	4
Vihiga	Western	2	4
Uasin Gishu	Rift Valley	3	4
Total		**18**	**30**

Table 10. Summary of ponds stocked and reported harvests for the Central and Eastern on-farm trials prior to final meeting.

District	Ponds Stocked	Ponds with Reported Harvest
Embu	7	5
Murang'a	11	9
Nyeri	9	9
Kirinyaga	14	6
Kiambu	11	7
Total	**52**	**36**

Table 11 presents the harvesting data for all the ponds. More than 50% of the ponds reported gross annualized production of over 3 t ha^{-1} yr^{-1} (Figure 1). The overall average was 3,475 kg ha^{-1} yr^{-1}. Previous records indicate about 1 t ha^{-1} yr^{-1} as the average production for those ponds that actually had recordable harvests. Interviews with farmers indicated that they may have produced even less than 1 t ha^{-1} yr^{-1}. Most of the ponds in the Central and Eastern trials are located at rather high elevations except for those in Kirinyaga. For example, the Nyeri ponds are all at about 1,800 m elevation, and several of them are higher up Mt. Kenya than the government trout farm at Kiganjo. In on-farm trials conducted in Rwanda, gross annualized yields of 1,600 kg ha^{-1} yr^{-1} (with inputs of chemical fertilizer and cut grasses) were reported from the 1,800-m elevation zone, whereas the average for Nyeri was 2,474 kg ha^{-1} yr^{-1} (Veverica and Rurangwa, 1997).

Table 11. Data from ponds belonging to farmers who attended the final meeting for the Central and Eastern on-farm trials.

Farmer Name	Pond Code	Area (m^2)	Months	GFY[1] (kg)	GFY ha^{-1} (kg ha^{-1})	GAFY[2] (kg ha^{-1}yr^{-1})	Species Stocked[3]	Mgmt Level	Harvest Value (KSh)	Expendi-ture (KSh)	Net Rev. (KSh)	NAR[4] (KSh ha^{-1}yr^{-1})	Rev. Sold (KSh)	Remarks
Justin I. Mwangi	MRA11	50	9	20	4,000	5,333	C	High	2,800		2,800	746,667	2,600	10 kg est. remain. Farmer insists got total > 100 kg!
Nicasco Ndambiri	KIR10	261	9	77	2,950	3,934	Mixed, C	High	7,700	3,600	4,100	209,451	6,200	
Nicasco Ndambiri	KIR11	54	9	46.7	8,648	11,531	Mono, C	High	5,150	900	4,250	1,049,383	5,150	
Gikuuri S. Grp	EBU1-3	378	9	41.95	1,110	1,480	T + C all	Low	6,035	2,560	3,475	122,575	6,035	Data from all 3 ponds combined.
Henry Kamau	KIR6	504	11	134.8	2,675	2,918	Mono, Mixed, C	Low	13,480	1,760	11,720	253,680	12,480	\
A. Chuma	KIR13	170	9	0	0	0	Mixed, C	Low	0	1,250	–1,250	(98,039)	0	No fish harvested.
A. Chuma	KIR12	220	9	30.43	1,383	1,844	Mixed, C	Low	3,043	1,250	1,793	108,667	3,043	
Joseph Thuo	MRA3	80	8	10	1,250	1,875	Mixed, C	Low	1,000		1,000	187,500	1,000	Otter predation, pond too shallow.
Kihara Gathuri	KBU7	180					Mixed, C	Low						Not harvested yet.
Romano Koigi	KIR5	100					Mixed, C	Low						
Francis Ndonga	NYI3	150	10	24	1,600	1,920	Mono, C	Low	2,400		2,400	192,000	2,400	
Kiritu Gitahi	KBU6	150	8	24	1,600	2,400	Mono, C	Low	4,800	403	4,397	439,700	1,950	Avg. 250 g tilapia @ 50/=, some fish escaped.
Kuria Mukiri	KBU8	80	8	26	3,250	4,875	Mono, C	Low	2,600	2,440	160	30,000	1,000	Still some fish left.
Charles Njeru	EBU4	168					Mono, C	Low		320				
Charles Njeru	EBU5	112					Mono, C	Low		320				So far only 1.5 kg for home use, rest not harvested.
Romano Koigi	KIR4	70					Mono, C	Low						
Isaac Ndirangu	MRA1	130	9	8	615	821	C	Med	800		800	82,051	800	Most fish went away with flood water.
Peter Wangaruro	KBU5	90	11	35	3,889	4,242	C	Med	3,500	1,290	2,210	267,879	2,500	Inputs–wastes, blood, pig finisher.
Thomas Nguo	EBU7	102	9	1.5	147		Mixed	Med		472				Home consumption, not all harvested yet.
D.M. Kabia	NYI6	144	8	14	972	1,458	Mixed, C	Med	2,295	684	1,611	167,813	1,945	
John Ng'ang'a	MRA7	162	10	25.0	1,543	1,852	Mixed, C	Med	3,125	424	2,701	200,074	3,125	Mostly leaves besides manure + fert.
S. Mwangi	MRA6	100	10	20.2	2,020	2,424	Mixed, C	Med	5,920	984	4,936	592,320	5,920	Has re-stocked with fingerlings from Sagana.
Francis Waigwa	NYI2	119	10	28.5	2,395	2,874	Mixed, C	Med	2,850		2,850	287,395	2,850	
Sagana W. Grp. 105	NYI5	108	10	28	2,593	3,111	Mixed, C	Med	2,800	349	2,451	272,333	2,100	
M. Ndung'u	MRA5	100	10	30	3,000	3,600	Mixed, C	Med	3,000		3,000	360,000		Not sure when harvested.
Francis Ndonga	NYI4	108	10	32.4	3,000	3,600	Mixed, C	Med	4,830		4,830	536,667	4,830	
James Ngotho	MRA10	100	9	29	2,900	3,867	Mixed, C	Med	2,900	985	1,915	255,333	2,400	
Mishak Kiragu	MRA8&9	280	9	97.8	3,493	4,657	Mixed, C	Med	11,610		11,610	552,857	11,610	Both ponds combined.
Prisons Dept.	KBU2	94	9	40	4,255	5,674	Mixed, C	Med		535				Stolen fish est. at 40 kg based on samples.
D.M. Kabia	NYI7	120	8	12.2	1,017	1,525	Mono, C	Med	3,100	1,086	2,014	251,750	1,500	
Francis Waigwa	NYI1	104	10	16.5	1,587	1,904	Mono, C	Med			0		1,650	Water crisis a serious problem; lost many fish.
Peter Wangaruro	KBU4	100	11	20	2,000	2,182	Mono, C	Med	2,000	250	1,750	190,909	1,000	Catfish ate all tilapia.
J. Kibugu	NYI9	302	8	48.62	1,610	2,415	Mono, C	Med	5,750	345	5,405	268,460	4,770	
Thomas Nguo	EBU6	105	9	26.5	2,524	3,365	Mono, C	Med	2,650	472	2,178	276,571	2,650	
R.M. Wachira	NYI8	117	8	27	2,308	3,462	Mono, C	Med	2,940	2,895	45	5,769	640	
Simon Gachieki	KIR1	190	9	51.15	2,692	3,589	Mono, C	Med	5,115	300	4,815	337,895	5,115	
Prisons Dpt.	KBU3	101	9	58.5	5,792	7,723	Mono, C	Med		535			2,290	Stolen fish est. at 40 kg based on samples.
Limuru G. Centre	KBU1	128	9	84	6,563	8,750	Mono, C	Med	10,080	1,762	8,318	866,458	10,080	Inputs–manure, wheat bran, DAP.

1 Gross Fish Yield
2 Gross Annualized Fish Yield
3 C – *Clarias*, Mono – monosex tilapia, Mixed – mixed-sex tilapia
4 Net Annualized Revenues

During the plenary session of the final meeting, it was concluded that management intensity explained most of the high net revenues. When farmers saw the net revenues reported in terms of KSh ha^{-1} yr^{-1}, they realized that they really need to expand their total pond surface area if they want to make money. However, it was cautioned that, whereas lower-level management such as use of manures and leaves works well for small ponds, it becomes increasingly difficult to use only farm by-products as total pond area increases.

Almost two-thirds of the ponds resulted in net revenues exceeding KSh 250,000 ha^{-1} yr^{-1}; the average was KSh 310,832 ha^{-1} yr^{-1} (Figure 2). A university graduate who works for the government earns an annual salary of about KSh 240,000. However, we did not include the expense of fingerlings used to stock the ponds, which would bring the overall average down to KSh 242,000 ha^{-1} yr^{-1}, nor did we include the value of fingerlings harvested when calculating revenues.

Although the average gross annualized yield was higher in ponds stocked with monosex tilapia + *Clarias* than in ponds stocked with mixed-sex tilapia + *Clarias* (Table 12), statistical analysis of variance was not done because the assumption of equal variance by treatment was violated. The high-intensity management option resulted in much greater net yields than the medium- or low-intensity management options, but there were only three ponds that were classed as having high management intensity: one was monosex tilapia + *Clarias*, one was mixed-sex tilapia + *Clarias*, and one was *Clarias* only. It appears that increasing management intensity is the first priority for fish farmers, and changing the species mix or switching to monosex should be considered only after that is done. This corroborates what farmers have been told for the past few years: If there is no food in the pond, it does not matter what kind of fish you have; nothing will grow. If we eliminate the three high-intensity management ponds and examine the medium- and low-intensity ponds, it appears that farmers are slightly better off if they increase management intensity from low to medium rather than switch from low-intensity mixed-sex to low-intensity monosex. In terms of net revenues, mixed-sex medium management gave greater net revenues than did monosex medium management. However, farmers did not report any expenditures for most ponds stocked with mixed-sex fingerlings, whereas all ponds stocked with monosex had expenditures reported.

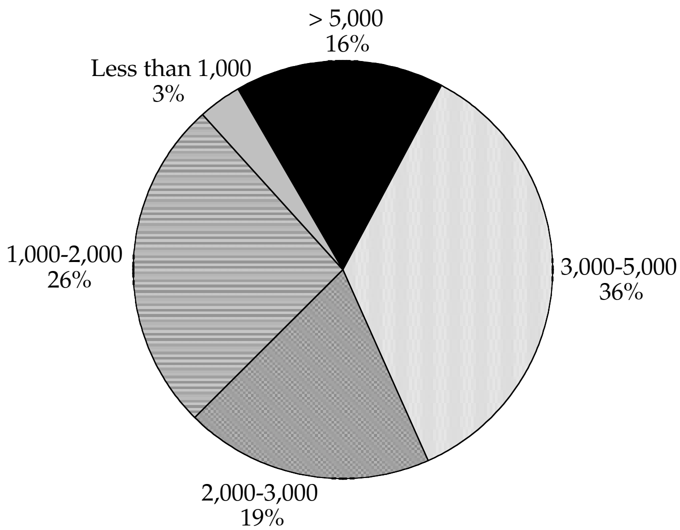

Figure 1. Percent of on-farm trial ponds that harvested each production category, expressed as gross annualized production (kg ha^{-1} yr^{-1}).

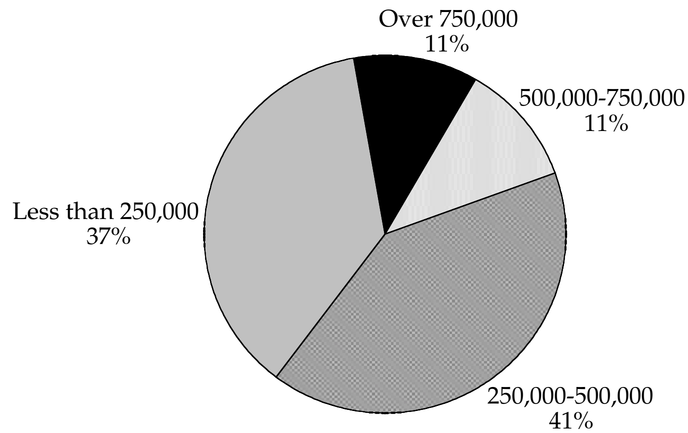

Figure 2. Percent of on-farm trial ponds in each net revenue category, expressed as net annualized revenues (KSh ha^{-1} yr^{-1}).

Farmers Questionnaire

Farmers said they were satisfied with the extension services offered by the Fisheries Department during these trials; the few exceptions came from Kirinyaga district (Table 1). The few people who were not sure about the quality of the services cited infrequency of visits in the case of Kirinyaga, lack of gear in Murang'a, and the apparent lack of technical expertise of extension agents in Kiambu. Suggestions to improve the extension services point to the problem of transport for extension agents (Table 2). The agents themselves have cited this problem repeatedly, and transportation assistance provided by the on-farm trials was short-lived. The need for training was also apparent by the time the trials began, and training of extensionists is an intended benefit of on-farm trials. This problem has been remedied to some extent with the extension agent training program initiated in November 1999, but only a small percent of the extension agents have been trained.

The numerous options for feeding fish and fertilizing a pond were overwhelmingly cited as the new things the farmers learned during these trials (Table 3). This is not surprising since data collected by Molnar et al. (1999) also suggested that farmers needed more information about how to manage their ponds. The organizers of the trials were aware of this and took the opportunity to inform farmers. It appears that the water management question was adequately addressed in our field days, but controlling water flow-through may not have been a problem in 1999 and 2000, as Kenya had experienced one of its worst droughts in recent history.

Many of the farmers interviewed said either they could not remember previous production results or they never got anything from their ponds previously (Table 4). Of the individuals who actually had previous harvests that they reported, harvest from these trials ranged from 1.7 to 10 times greater as compared to harvests from previous years. The

Table 12. Average gross annualized fish yield (GAFY; kg ha^{-1} yr^{-1}) and net annualized revenues (NAR; KSh ha^{-1} yr^{-1}) grouped by management intensity and by species stocked. Some farmers combined data, which did not allow some comparisons to be made for their ponds. Several ponds at low management intensity were not yet harvested.

Management Option	GAFY (kg ha^{-1} yr^{-1})	NAR (KSh ha^{-1} yr^{-1})	Number of Ponds Reporting
INTENSITY			
High	6,933	668,500	3
Medium	3,481	320,696	21
Low	2,164	154,510	8
STOCKING			
Tilapia Monosex + *Clarias*	4,280	355,354	13
Tilapia Mixed-sex + *Clarias*	2,912	279,413	14
Clarias Only	3,465	365,532	3
COMBINED INTENSITY AND STOCKING			
Medium Monosex + *Clarias*	3,879	313,973	9
Low Monosex + *Clarias*	3,065	220,567	3
Medium Mixed-sex + *Clarias*	3,312	358,310	10
Low Mixed-sex + *Clarias*	1,623	114,876	5

average was a 330% increase in harvest. This corroborates the estimated increase in production based on previously estimated average annual production of 1 t ha^{-1} yr^{-1}. The overall average for these trials was 3.5 t ha^{-1} yr^{-1}.

More than one-third of the farmers used their revenues for further pond management or renovation (Table 5). However, it is difficult to say how many of those who used the revenues in their general family operating budget also spent some of it on the ponds. One of the problems associated with increasing management intensity is that farmers have trouble saving some of the revenues to re-invest in their ponds. It appears that this was not the case with most of the farmers in this trial. It also seems that farmers were able to use some of the revenues to directly aid in family expenditures. This is the reason the ponds were there in the first place.

The way the farmers will change their management is interesting (Table 6). It appears that the increase in production during these trials resulted from better management, e.g., more frequent feeding and fertilizing, due to the fact that visitors were coming to see how the farmer and pond were doing. At the beginning of the trials, the farmers were not necessarily of the opinion that better management would result in better and more profitable production. However, after seeing what the high and medium management levels produced, they were convinced. It remains to be seen if they were convinced sufficiently to maintain the higher management levels in coming years or not. The other responses farmers gave demonstrate that the pond is considered a viable source of revenue. For example, several farmers reported a demand for fingerlings in their area, and they hope to supply this demand. Others will increase pond size and number (Table 6).

When asked how many other people knew that they were involved in the trials and what was going on, many farmers neglected to mention family members and were very conservative about numbers (Table 7). Perhaps they thought our next question would be to name the people who knew. The next questionnaire will ask specifically how many people from each category knew about the trials. According to the farmers, almost 1,000 people knew about the trials. According to extensionists, there were well over two times that number (Table 8). It therefore looks as if there was at least a 10:1 multiplier effect. More people may be in contact with the farmers later as well. The farmers reported a total of 62 people who they know want to begin fish farming, another 31 who have already begun, and 28 new ponds constructed so far (Table 7). The farmers themselves may become the advisors to these beginners because they see the potential for fingerling sales.

One of the notable things to come out of these trials was the farmers' eagerness to pay their own way for training sessions. Several of them asked if they could attend training at Sagana if they paid for their own lodging and meals. Production of tilapia and *Clarias* fingerlings, pond harvest techniques, and gear were most frequently requested subjects for further training.

Extension Agents Questionnaire

A separate set of questions was asked of the extension agents. They responded in much the same way as the farmers. They cited lack of transport, lack of gear, and lack of technical training as constraints to their job. The trials afforded them a broadening of experience. Those who attended training sessions before or during the on-farm trials felt more confident in their job. Their responses to the question asking what new things they learned were very much the same as the farmers' responses.

CONCLUSIONS AND RECOMMENDATIONS

Pond management, including water flow control and feeding and fertilization options, has been one of the biggest problems in aquaculture extension in Africa. These trials have helped farmers and extensionists to gain a better understanding of pond management. It is hoped that the Kenya Fisheries Department under the Ministry of Agriculture and Rural Development will continue to train its extension agents in pond management and, once agents are trained, provide them with sufficient transport opportunities to make frequent visits to farmers. In areas where fish culture will be practiced in a few small ponds per family, extension efforts should be concentrated for some years to bring farmers' understanding up to speed but then can be cut back to fewer visits by more highly trained extension specialists. Field days and annual meetings can be used to pass on information after the farmers have graduated from the intensive extension effort.

The small seines assigned to the extension offices have been of immense value. Most farmers in the Central and Eastern Provinces make partial harvests of their ponds over a period of several months, and the seines facilitate this. While partial harvesting is good from the biological production point of view, it can cause problems in tilapia ponds because of tilapia's prolific nature. Some of the problems are listed below:

- Large fish are removed first, thereby leaving the slowest growers as broodstock, and skewing the sex ratio towards female.
- A large biomass of fingerlings accumulates, and growth can virtually cease. The farmer delays draining the pond because the fish are not yet large enough but does not understand that the pond has reached carrying capacity.
- Predators such as *Clarias* can reach large sizes if they evade capture, and they will target larger tilapias, not the fingerlings.
- If draining does occur, large fingerlings are often selected for re-stocking, but farmers do not distinguish between large fingerlings and stunted females.

The extension service and farmers should be made aware of the problems associated with partial harvest. The best recommendation would be to drain and dry the pond after a maximum of 12 months and to restock with fingerlings produced by well-selected broodstock. Partial harvests should not be forbidden by the extension service because farmers will do them any way. The PD/A CRSP in Kenya has not yet done any research on partial harvesting options.

There were some problems with farmers thinking the fish belonged to the Sagana Station because the fingerlings were given free of charge. Some farmers were reticent to report harvests or sales for this reason. The free fingerlings also attracted farmers who probably should not have been in the trials. The fingerlings for western Kenya will not be given free of charge, but the project will make a considerable investment in getting the fingerlings to the farmers and in helping farmers meet the costs. Another problem, isolated to one district, seemed to be the "ownership" of the data from the ponds.

The fisheries officers in most districts were extremely helpful and recognized the contribution required of the Kenya Fisheries Department. They helped in sampling and compiling harvest data. The farmers did as well. This study financed almost all of the transport required for the trials, which allowed the officers and extensionists to make the visits. For the next set of trials, to be conducted in western Kenya, we recommend that the fisheries officers report the harvest data in separate reports for their districts and that these reports be cited as sources.

ANTICIPATED BENEFITS

This is the first set of trials in which stocking strategies and management options on farms in Central and Eastern Provinces have been systematically examined. Although the climate is cooler in Central Province compared to many parts of western Kenya, it was relatively easy to obtain a three-fold increase in production. Farmers evaluated and compared alternative technologies and made informed decisions about increasing fish production in their own ponds. Record keeping was greatly enhanced, and its value in future decision-making was appreciated. These trials immediately increased interest in fish farming, and many of the farmers who participated in the trials will be seen as models for new beginners. The trials also led investigators to management questions of interest to fish farmers such as possible partial harvest strategies and potential *Clarias* growth rates at higher elevations.

ACKNOWLEDGMENTS

Several individuals made outstanding contributions towards conducting and completing the Central and Eastern trials and towards getting the Western trials started. These include J. Amadiva and E. Mac'Were, who gathered data from farmers and offered advice; many fisheries officers and the extensionists working with them, who gathered and recorded sampling data; E. Mac'Were, who entered the sampling and harvest data on a standardized spreadsheet (he also included his notes on management level and types of inputs used; these were used to verify harvest data reported by the farmers and to attribute a management level to each pond record); and Charles Ngugi and E. Mac'Were, who re-verified harvest data at the final meeting.

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