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ECONOMIC DIFFERENTIAL OF INTEGRATED FISH, RICE CUM PIGGERY AND FISH, RICE CUM POULTRY PRODUCTION SYSTEMS

Olapade OJ[1*], Bangura H[1], Tholley JB[2] and RR Momoh[3]

Olapade Julius Olufemi

*Corresponding author email: Julius.olapade@yahoo.co.uk fem66@hotmail.com ojulius@njala.edu.sl

[1]Department of Aquaculture and Fisheries Management - School of Natural Resources Management, Njala University, Njala, Sierra Leone

[2]Faculty of Agriculture and Food Sciences University of Makeni (UNIMAK), Sierra Leone

[3]Department of Extension and Rural Sociology School of Agriculture, Njala University, Njala, Sierra Leone

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ABSTRACT

Sustainability of any aquaculture venture especially for enhanced food security and socio-economic development of the target population is the challenge of the new millennium. With the right environment and best management practices (BMPs), the envisaged expectations of the integrated investment can be achieved. This paper compares the economic performance and environmental friendliness of two adaptive integrated aquaculture systems at Njala University fish farm, Sierra Leone. The studies were carried out for six months (June-November, 2014). Fish, rice cum piggery and fish, rice cum poultry production integration platforms were set up to perfect the ideas of integrated fish farming in Sierra Leone. Water quality parameters measured bi-weekly included: dissolved oxygen, water temperature, pH, water hardness, water alkalinity, ammonia, nitrate, BOD and nitrite. These parameters were determined using Jenway analytical probes and Pondlab multi-parameter kits. Three samples were collected in thoroughly washed 600ml water bottles at each sampling point. Water quality parameters determined in the studies were found to be within the recommended range for the culture of tropical fish species and were not also statistically significant ($p<0.05$). However, the pH of adaptive research platform (ARP) was slightly acidic. Economic analysis gave a negative incremental benefit and Net Present Value (NPV) for the fish, rice cum piggery synergy in the first year. The calculated benefit/cost ratio for the pig, rice cum piggery production was positive but below 1 (0.87).The system had a negative NPV (-Le 2,990,708), and a payback period of 1.33 years; a net profit of Le 8,944,000 with a gross profit margin of 0.46. The fish, rice cum poultry production, however, gave a positive NPV (Le 841,930.32 (US189.3)) and a cost – benefit ratio of 1.02. Net profit, Gross Profit Margin and the payback period calculated for the investment were Le 13,892,000, 0.34 and 0.98 years, respectively. The poultry project broke even and payback in the first year while the piggery project did not but can only break even and pay back in the second year of production. The culture of genetically poor fish fingerlings, high construction costs of the adaptive research platform, scale of operation and pricing of the farm produce were seen as major causes of reduced profitability. The results obtained from the study, clearly indicate that the two integrated synergies have the potential to help solve the problems of hunger and poverty in Sierra Leone, especially among the rural poor that constituted more than 70% of the population.

Key words: Cost-benefit, Integrated aquaculture, Water quality, Sierra Leone, grassroots farmers

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INTRODUCTION

Aquaculture plays a very significant role in offering employment/labor to millions of people along its divergent value chain, in addition to providing food and nutrition security to fisheries-dependent communities and the wider society. Aquaculture is a major source of livelihoods to a wide range of stakeholders that encompass farmers, feed millers, processors, marketers and providers of other ancillary services. Aquaculture has the potential of increasing fish supply and, thereby, meeting fish demand. This sub-sector of the economy has been recognized as an important source of production for meeting the ever increasing demand for animal protein. However, the pace of development of aquaculture in Sierra Leone is slow and discouraging despite the huge availability of land, water, agro - inputs and ready markets. This slow development is due to factors such as weaknesses in both research – knowledge base and commercialization of aquaculture technologies, and poor aquaculture infrastructure base coupled with unavailability of key farm inputs such as fish seeds and feeds. The agricultural transformation agenda of the government focuses hugely on food security and prosperity and for these to be actualized there is the urgent need to revisit existing technologies with the aim of refining them and also pursuing new methods of improved aquaculture practices. With the anticipated negative global effects of climate change on the world water and its fisheries, Sierra Leone needs to wake up to the adaptive reality of aquaculture. Integrated aquaculture, which link aquaculture to conventional farming systems will be the most appropriate weapon to fight hunger and poverty in sub-Saharan Africa. The development of such systems has been driven by different needs in different parts of the world, including a desire to improve food security on small, subsistence family farms; or to minimize pollution and use valuable resources (such as water) more efficiently and effectively. Integrated Aquaculture Agriculture Systems practices were established long ago in many Asian countries for subsistence purposes, but are increasingly being developed for more commercial, income generating purposes in both Asia and developed "Western" countries. The practice represents a new way of farming in Africa. The principle behind integrated agri-aquaculture business is the maximal use of all available land and water resources. Integrated pig/fish/rice or poultry/fish/rice production is a promising way of making the most of a smallholder farmer`s land and labour. Economic studies have shown that a traditional production system is wasteful and unprofitable due to poor feed conversion, high mortality rates, low reproductive rates and final products [1]. It is now established that integrated fish cum livestock farming is a good strategy that can be adopted by small-scale farmers in developing countries to boost farm yield and returns. The present study compares the economic performance of two integrated adaptive research systems – fish, rice cum piggery and fish, rice cum poultry production with the mindset to advance their strong and weak economic points. The paper also seeks to identify areas where costs could be pruned in order to make the innovation feasible, viable and attractive to poor rural farmers.

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MATERIALS AND METHODS

Description of the Study Area

The adaptive research trials were carried out at Njala University Fish Farm, Sierra Leone (Figure 1). Njala University experiences two seasons, the dry season which spans from mid-November to early April and the wet season from mid-April to early November. Daily mean temperature of the study area ranges from $21^{0C}$to 23^{0C} for the greater part of the dry season [2].

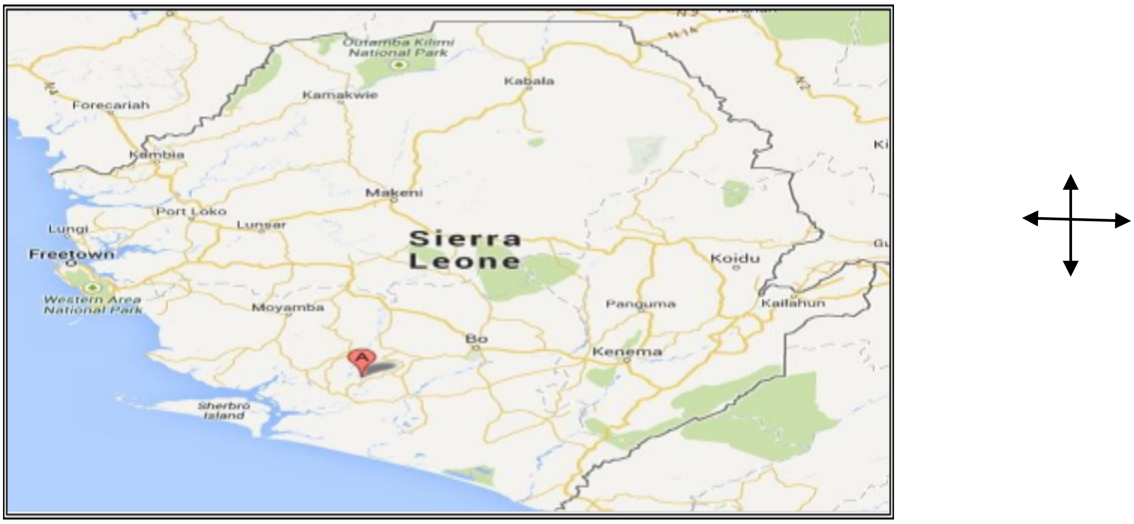

Figure 1: Map of Sierra Leone showing Njala University (dotted red)

The integrated fish, rice cum piggery adaptive research platform design

The adaptive research platform consisted of the pigsty (2.5m x 11m in dimension) partitioned into three units with wastes discharge channels: the maggotry made of bush stick and corrugated iron sheet with a rice paddy platform (187m^2). The integrated research platform has a surface area of 395.2m^2 (Plate 1).

Plate 1: Experimental design (Pigsty directly at the head of the pond shaded by mango trees)

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Piggery production

A large white in-gilt pig and eight weaners were bought from Manjama Institute of Agriculture (MIA) in Bo, Southern Sierra Leone. The animals were housed in the pigsty constructed for the research platform. Management practices carried out on the animals included feeding to satiation once daily, washing of the animal severy three days and random weighing every month. The pig feed consisted of palm kernel cake, salt, fish scraps, rice bran, corn meal and a little addition of bone meal. The animals were also fed regularly with leafy vegetables and fruits such as *Ipomoea reptans* (gogodi), *Alternanthera braziliana*, pawpaw leaves and fruits (this contains piperazine, which serves as dewormer). Mango fruits were also given to them when available. Wounds sustained through wall rubbing were treated with Gentian Violet and disinfection was carried out with Dettol and Izal.

Plate 2: The pigsty and the pigs (feeding time)

The fish, rice cum poultry adaptive research platform design

The adaptive research supported by CORAF/WECARD through the Multi Donor Trust Fund (MDTF) lasted six months (June – November, 2014). The adaptive platforms consisted of a poultry unit(3.5m x 11m) designed to house 400 broilers from day- old chicks to table size (reared for 2½ months); an integrated pond - 520m^{2}surface area partitioned into 300m^2 for fish culture and a centralized paddy platform of 200m^2 for rice cultivation. A separate pen made of wood and corrugated iron sheets netted with chicken wire mesh was constructed for maggot production (Plate 3).

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Plate 3: Fish, Rice and Poultry Integrated unit set up

Poultry production

Day-old chicks (400 in number) used for the research were bought from Pajah hatchery at Lumley in Freetown (203 km from the university). The chicks were brooded using charcoal as a source of heat for a period of three weeks. The chicks were vaccinated against Gumboro and Newcastle diseases and this was done in the second and fifth week after arrival, respectively. Prophylactic drugs (antibiotics) were administered every three days to forestall the occurrence of disease outbreaks, especially diseases caused by bacteria. Multivitamins (growth booster) were added to the chicks' water to boost their appetite for feed. Feed and water were given *ad-libitum*. Hanging water troughs were adjusted to the reach of the birds for the first one month and half but as the bird grew and demand for water increased, five - liters plastic bowls were used. The bowls were covered with guards to prevent the chickens from defecating in the water and also to prevent them from drowning. Starter feed used for raising the chicks was obtained from Pajah farm but the finisher was compounded at the Department of Aquaculture and Fisheries Management, Njala University using locally available ingredients.

Cultural practices

Cultural practices carried out for the integrated platforms included transplanting of nursed NERICCA 19 rice at a spacing of 20cm inter – rows and 5cm intra – rows, and the application of organic manure at the recommended rate of 150kg fresh manure/ha/day. Organic manure was applied twice a month in a bid to avoid the problem of overloading that could lead to water chemical imbalance. Weed was manually removed twice a month (rouging). Water in the integrated pond was kept low

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at the level of the paddy platform to prevent the young seedlings from logging by simply lowering the stand pipe at the outlet.

Fish culture

Fish used for the research were obtained from fish farmers` group at Magbosie village. *Clarias gariepinus* juveniles' mean weight 25.6g and 25g, respectively was stocked at a density of 4.8fish per $m^2$and 2fish/m^2, respectively. The fish were acclimated for three days prior to the commencement of the research. The acclimated fish were then introduced into the ponds and fed at 5 per cent body weight; feeding was adjusted every month to attune to weight gain. Fish were fed homemade sinking pellets, supplemented with maggots generated from the poultry pig manure.

Plate 4: Harvested fish (Undergraduate students sorting out the fish)

Maggot Production from chicken and pig manure

Wastes from the piggery pen and the poultry house were converted into maggots used as supplementary feeds for the fish. A maggotry was constructed using bush sticks, wire mesh and corrugated iron sheets. Wastes were placed in bags and plastic bowls; wet with water and layered with handful of rice bran for ease of maggot production and were kept for seven days (Plate 5). Maggots produced were sieved on day seven; the remaining digested waste was used to fertilize the integrated fish pond.

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Plate 5: The maggotry

Water Quality Assessment

Water quality variables measured every two weeks for the two platforms were dissolved oxygen, water temperature, pH, water hardness, water alkalinity, ammonia, nitrate, BOD and nitrite. Jenway analytical probes and Pondlab multi-parameter kits were used to determine the levels of the variables. pH, water temperature and dissolved oxygen were determined *in–situ* while water samples were collected at three different points for water alkalinity, ammonia, nitrate and BOD. Samples were collected at the inlet point, mid – water and near the water outlet point. The collected samples were fixed with one percent concentrated nitric acid(HNO_3) and preserved in the refrigerator at 4^oC prior to analysis in the laboratory.

Statistical Analysis

Data for water quality variables were analyzed using measures of central tendency (mean and standard deviation) and one-way analysis of variance (ANOVA) at P=0.05. Significant differences were separated using the least significant difference (LSD).

Economic analysis

Production costs, and gross revenues, cash flow, sensitivity of the project, gross merging and benefit – cost ratio were evaluated for the two projects using the formulae below.

Incremental benefit = Revenue – Costs
Discounted costs = Discount factor (15%) multiplied by Costs
Discounted revenue = Discount factor (15%) multiplied by Revenue
Net Present Value at 15% = Discounted revenue – Discounted costs
The discounted factor at 15% was calculated as follows
Year 1 = $1 \div (1 + 15\%)^1$
Year 2 = $1 \div (1 + 15\%)^2$

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Year 3 = 1 ÷ $(1 + 15\%)^3$
Net profit = (Gross revenue) – (Total operating costs)
Gross profit margin = (Gross profit) ÷ (Gross revenue)
Payback period = (Total capital cost) ÷ (Net profit)
Benefit – Cost Ratio = Discounted Revenue ÷ Discounted Costs

RESULTS

Physico-chemical Parameters

The results of the water quality parameters determined in this study are presented in Figures 2, 3 and 4. The values are statistically related and are within the range recommended for the culture of tropical fish species. Nitrate – Nitrogen and Ammonia/Ammonium (NH_3/NH_4) were not detected in the ambient water of the adaptive research pond.

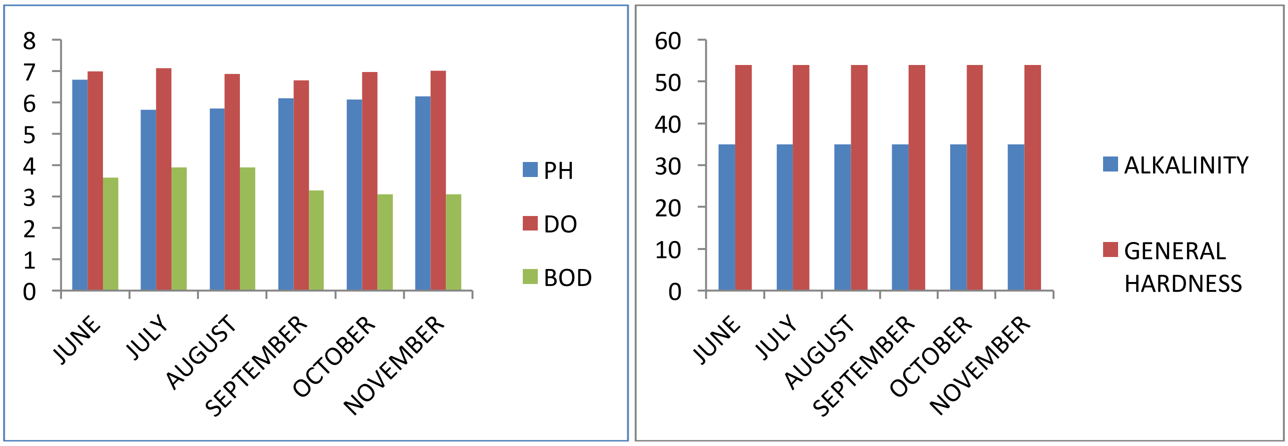

Figure 2: Some physico-chemical parameters of the fish, rice cum piggery integration

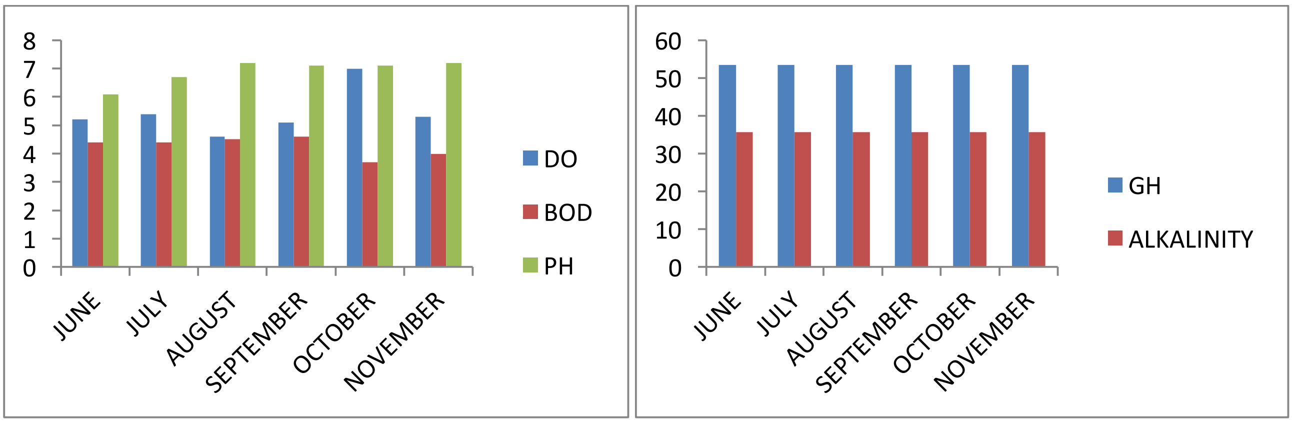

Figure 3: Some physico-chemical parameters of the fish, rice cum poultry integration

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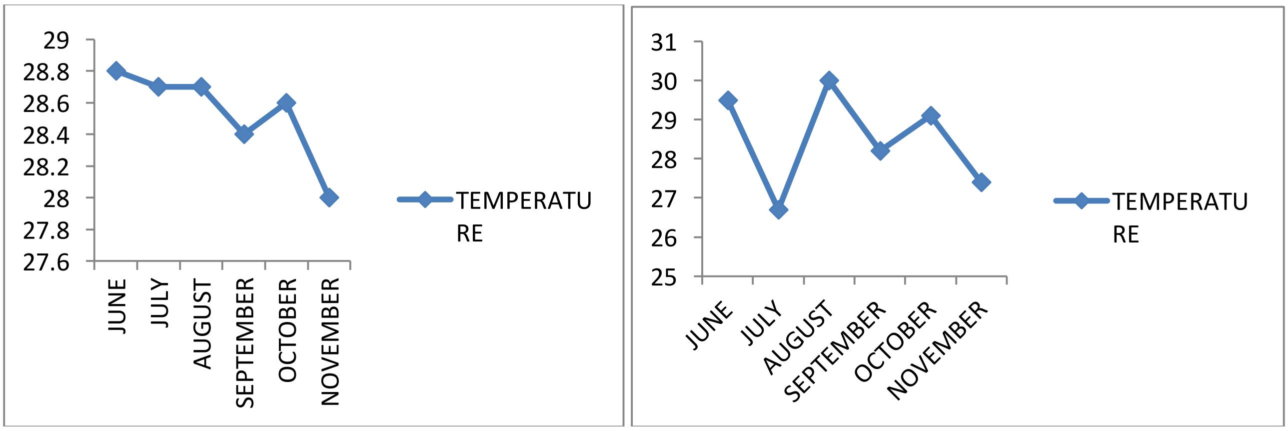

Figure 4: Temperature readings of the piggery and poultry integration, respectively

The *p*H of the study area especially for the piggery project with the exception of June was slightly acidic and was below the level of 6.5 – 8.5 recommended while that of the poultry project was within the recommended limit. Mean dissolved oxygen range of 6.7 – 7.09 and 4.60 – 7.00 mgL^{-1} recorded for the piggery and poultry projects is ideal for the culture of C. *gariepinus* and other tropical fish species since it exceeds the $4.00mgL^{-1}$ critical limit for most tropical bony fishes.

The temperature readings recorded for the two projects were within the range of 21^oC – 32^oC for fish ponds in the tropics. Nitrate –nitrogen and ammonia – ammonium was not detected in the pond water throughout the experimental period. . Mean general hardness recorded was within the range of 50 – 300ppm recommended for the culture of African catfish while the alkalinity was below the recommended range.

Economic performance of the adaptive research platforms

The results of the performance of the adaptive research platforms are presented in Tables 1, 2, 3 and 4. Table 1 presents the budget-cost and revenue of the piggery integration, while Table 2 presents the cash flow analysis of the investment. Budget costs and revenue of the poultry integration are presented in Table 3 while the cash flow analysis is presented in Table 4.

Economic analysis gave a negative incremental benefit and Net Present Value (NPV) for the fish, rice cum piggery synergy in the first year. The calculated benefit/cost ratio was positive but below 1 (0.87). Net profit, Gross Profit Margin and the payback period of the investment were Le 8,944,000 ($2,010.8), 0.46 and 1.33 years, respectively. The fish, rice cum poultry production, however, gave a positive NPV (Le 841,930.32 (US189.3) and a positive cost – benefit ratio of 1.02. Net profit, Gross Profit Margin and the payback period calculated for the investment were Le 13,892,000 ($3,123.2), 0.34 and 0.93 years, respectively.

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DISCUSSION

Water quality

The water quality parameters determined for this study were within the limit recommended and will support both the culture of tropical fish species and the cultivation of rice [3, 4]. The water parameters were not significantly different although there were variations within the system. Variations are known to exist between the different environmental compartments in aquatic ecosystems especially with regard to physical, chemical and biological characteristics.

The low acidity of the pond water could be attributed to the fact that the soil of the study area is acidic and also probably due to buffering effect of River Taia, which back flushes into the wetland area where the study was conducted. Photosynthesis by phytoplankton is the primary source of dissolved Oxygen in aquatic ecosystem [5]. Foraging fish in integrated plots are known to consume organic matter thereby reducing the requirement for dissolved oxygen significantly by such organic matter [6]. Perturbation of the soil by fish can also result in aeration of soil and water and this could have been responsible for the dissolved oxygen level recorded in the study. This might be due to the controlled organic loading of the ponds and the pond water carrying capacity. The mean general hardness and alkalinity of the two systems was the same.

Economic Performance of the adaptive research platforms

Economic analysis gave a negative incremental benefit and Net Present Value (NPV) for the fish, rice cum piggery synergy in the first year. The poultry project broke even and pay back in the first year, while the piggery project did not but can only break even and pay back in the second year of production. Most investors find projects with short payback periods more economically attractive, especially in markets that are lacking credit facilities. Aquaculture business which takes five or more years to pay back the costs of investment is considered to be unattractive [7]. Hence, this could serve as an encouragement to investors who normally would prefer a short- term investment as a measure of reducing risk. Risk is time related in the sense that the longer it takes for an investment to recoup its costs, the greater the risk of failure. In this study, it was observed that certain factors contributed to the negative incremental benefit and NPV recorded for the fish, rice and piggery integration. These factors include the high initial capital outlay especially in the construction of the pigsty and the paddy pond; the scale of production of both the piggery and the paddy pond is assumed to be highly germane to the profitability of the investment. Other factors that require special attention in order for the investment to be profitable are physical factors; which include the environmental conditions of the farm area. Yields from the investment can be affected by either of topographies (sources of water supply, water quality, type of soil, and weather), types of fish pond, and farm sizes. Yields are known to be sensitive to physical factors, farm size, farm type and stocking rate. Besides the stocking rate, the type of fish stocked also to a great extend determines the returns on investment. In this study, fish stocked were sourced from the wild since there was no catfish hatchery in Sierra Leone from where genetically sound fish seeds could be bought. Importing fish from abroad attracts a lot of money and immigration restrictions. Consequently, the high mortality recorded as a result of the source of the fish grossly affected the revenue

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by reducing the overall incremental benefit of the investment. The survival rate determines the quantity produced at the end of the production period [8]. Increasing mortality rates lead to low survival rate and thus lower yields. Higher yields coupled with good prices are needed to increase revenue and thus profitability.

The findings of this study show disparity in pricing of the farm produce. In the capital city (Freetown), a pound of pork sold for Le 11,000 ($2.47) as against Le 7,000 ($1.57) that was sold to the university community – a big gap of Le 4,000. In Nigeria, a kilogram of catfish sells for ₦ 500 (US$ 3.03) farm gate prices, whereas it was sold at Le 10,000 (US$ 2.25) in Sierra Leone. Increasing the selling prices of both the pork and the fish to match current market prices elsewhere will make the investment profitable and highly attractive to farmers. To achieve better and quicker returns, especially in a country like Sierra Leone, availability of key inputs such as genetically proven fish species, and good quality fish feed used as a supplement to maggots are imperative. Sourcing fish seeds from the wild will lead to stunted growth and bad returns and procuring them from overseas will increase the cost of production, with attendant longer payback period. From the findings of this study, it is evident that importing day-old chicks to Sierra Leone and thereafter re-selling them to farmers will exacerbates the cost of production unnecessarily; therefore, it is advisable for government or other non-governmental organizations with bias for agriculture to intervene with regards to setting up hatchery to hatch chicks locally. Njala University for the first time in the history of the country took the initiative to commence the breeding of genetically proven C. *gariepinus* fingerlings and juveniles locally. Genetically and phenotypically sound broodstock were pulled together from the adaptive research plot with Deutch Clarias imported from Lagos, Nigeria. This was made possible through the grant provided by CORAF/WECARD.

CONCLUSION

A range of public and private sector investments and initiatives are needed to realize the potential for the development of integrated fish farming, especially in the area of supply of inputs such as fingerlings, feeds, seeds and other ancillaries. Public private partnerships offer potentially important opportunities for pro-poor agricultural development. Such collaborations have already contributed to food security in many developing countries. It was also noted that the price at which the pork and table fish were sold is below what is obtained elsewhere, especially in the urban cities. Therefore, it is recommended to raise the market price for a kilogram of fish from Le 10,000 (US$ 2.25) to Le 15,000 (US$ 3.37); while that of pork from Le 7,000 ($1.57) to Le 9, 000 (US$ 2.03); this will enhance quicker returns on investment and early pay back of invested costs and encourage farmers to adopt the innovation. To make the best out of the integrated fish farming investment, increasing the scale of production for pigs, rice and fish has been found to be related to increased profitability.

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Table 1: Budget – Costs and Revenues of the piggery integration

1ST YEAR OF OPERATION (1ST PRODUCTION CYCLE)	
FIXED CAPITAL EXPENSES	
1. construction of piggery house	Le 8,363,474
2. construction of maggotry	Le 70,000
3. construction of fish pond	Le 2,221,234
4. Equipment	Le 1,280,000
Operating Expenses	
1. Stock	
Purchasing of pigs	Le 1,300,000
Fish seeds (2000 *Clarias gariepinus*)	Le 1,400,000
Rice seeds (NERICA 19)	Le 20,000
2. Labor	
Permanent and Hired	Le 2,400,000
3. Feed	
Piggery feeds	Le 2,500,000
Fish feed	Le 2,388,000
4. Others	
Chemical lime and disinfectants	Le 50, 000
Drugs and disinfectants	Le 500,000
Summary of cost	
Fixed capital	Le 11,934,708
Operating expenses	Le 10,558,000
Total	**Le 22,492,708**
Revenue	
Rice	Le 140,000
Fish	Le 12,400,000
Pigs	Le 6,812,000
Sales of manure	Le 150,000
Total	**Le 19,502,000**

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Table 2: Cash flow analysis for the piggery Integration

Cycle	Costs	revenue	Incremental Benefit (1)	Discount Factor at 15% (2)	Net Present Value at 15% (3)	Discounted Costs (4)	Discounted Revenue (5)
1	22,492,708	19,502,000	-2,990,708	0.87	-2,601,915.6	19,568,656	16,966,740
2							
3							

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Table 3: Budget – Costs and Revenues of the poultry integration

1st Year of Operation (1st production cycle)

Fixed Capital Expenditure		
Construction of poultry house		8,343,250
Construction of maggotry unit		70,000.00
Excavation of pond		2,856,234
Purchase of farm equipment		1,654,780
Operating Expenses		
I.	**Stock**	
	1200 broilers at Le 6,850/day old chick	8,220,000
	2000 fingerlings at Le 700/fish	1,400,000
II.	**Labour**	
	Farm hand and harvesters	3,500,000
III.	**Feed**	
	a. Fish feed	2,388,000
	b. Poultry feed	9,327,000
	c. Vaccines and antibiotics	1,562,000
	d. Chemical lime and disinfectants	50,000.00
IV.	**Others**	
	a. Charcoal (15 bags at Le 12,000/bag)	180,000.00
	b. Kerosene (10 gallons at Le 22,500/gallon)	225,000.00
	c. Growth boasters (12 sachets at Le 13,782/sachet)	165,384.00
Summary of Costs		
	Fixed Capital	Le 12,924,264.00
	Operating Expenses	Le 27,017,384.00
	Total	Le 39,941,648.00
Revenue		
1200 broiler birds (9.3% mortality) at Le 25,000 per bird		Le 27,407,384.00
2000 table fish (less 35% mortality & weight adjustment @ Le 10,000/kg fish)		Le 13,000,000.00
Poultry manure (Use and sale)		Le 350,000.00
Harvested rice (50kg)		Le 152,000.00

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Table 4: Cash flow analysis for the poultry integration

Year	Costs	revenue	Incremental Benefit (1)	Discount Factor at 15% (2)	Net Present Value at 15% (3)	Discounted Costs (4)	Discounted Revenue (5)
1	39,941,648	40,909,384	967,736	0.87	841,930.32	34,749,233.8	35,591,164.1

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