

CAN INTEGRATED LIVESTOCK-FISH CULTURE BE A SOLUTION TO EAST AFRICA'S FOOD INSECURITY? A REVIEW

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ABSTRACT

Integrated livestock-fish culture approach envisages the integration of fish farming with cattle, sheep, goats, poultry, pigs or rabbit husbandry in a design allowing wastes from one system to be used as inputs in another system. The aim is to conserve resources while increasing farm returns. This paper reviews integrated livestock-fish culture in Asia and some African countries towards stimulating growth in East Africa's livestock-fish integration practices. Livelihood challenges and current status of integrated livestock-fish culture in some segments of East Africa are discussed. Economic analyses of integrated livestock-fish farming in selected places are presented. Challenges facing integrated livestock-fish aquaculture in the region include: government neglect of aquaculture sector, weak aquaculture research and applications, political interferences as well as social and religious challenges. Poor publicity, poor infrastructure, lack of clear legislations and policies and high illiteracy among potential fish farmers have also been mentioned as bottlenecks to the growth of integrated fish farming in the region. So far, fish-poultry integration is the most popular across Africa and Asia while fish-cattle integration is unpopular in many countries. Livestock manure as source of organic fertilizer for fish ponds and biogas production can help reduce cost of investment in purchasing inorganic fertilizers. With the present high cost of pelleted fish feeds, integrated fish farming stands to reduce the cost of feeding fish while simultaneously increasing the yield, leading to high economic returns. This paper concludes that livestock-fish integration is one of the most practicable solutions to food insecurity and malnutrition in the East African community despite its current poor status. In fact, it could be the forgotten asset that can guarantee present and future aquaculture sustainability in the region. The paper recommends capacity building among stakeholders to recognise integrated aquaculture as a 'self feeding' biotechnology unit, which deserves special attention in East Africa.

Key words: livestock-fish culture, integration, East Africa

INTRODUCTION

Aquaculture is the controlled land-based or open-ocean farming of aquatic organisms such as fish, shellfish and even plants. Aquaculture contributes to human food fish demands, poverty alleviation and rural development and is often mooted as the fastest growing food production sector in the world [1]. Integrated Agriculture Aquaculture (IAA) combines aquaculture with different agricultural systems into an interactive relationship with the expectation that together, they will generate synergistic effects on conservation of resources and profitability [2, 3]. Livestock production and processing generate by-products that may be important inputs for aquaculture. The main linkages between livestock and fish production involve the direct use of livestock wastes, which function as fertilizers to stimulate natural food webs in fish ponds. The concept of Integrated Agriculture Aquaculture System (IAAS) was first conceived and explored in Asia in the late 1970s due to limited wild fish stocks; limited land space and high human population to fulfil food requirements [4, 5, 6]. Since then, some of these systems have been successfully applied in other developing countries and impressive yields have been reported [7]. Today, aquaculture production stands at 50:50 to capture fisheries on a global scale thanks to the technological advancements such as hybridization, genetic engineering, formulated diets and the integrated agriculture aquaculture [8]. However, the rate of aquaculture production is not uniform the world over [9]. In Asia, which is the epicentre of aquaculture production, aquaculture is integrated with agriculture providing millions of livelihood opportunities [10]. However, Africa is yet to report any significant quantities of integrated aquaculture products despite the natural potential [11].

In Africa, integrated aquaculture is mainly for subsistence purposes often carried out in the family backyards and publications even in national documents are very scanty [12]. Nevertheless, successful application of livestock-fish farming in Asia is a testimony that indeed it is positively correlated to enhanced productivity, food security, profitability and environmental sustainability [13]. Therefore, there is need to perform research studies on specific aquaculture-agriculture combinations that can yield best results in Africa.

In East Africa, aquaculture is generally under-developed, contributing less than 1% of total global fish production [14]. Similarly, integrated livestock-fish culture is still at a rudimentary stage and few successful impacts are documented [15]. Integrated livestock-fish culture could be one of the potential solutions to the continuous food insecurity, malnutrition and poverty for the small-scale and marginal farmers in the region [15]. The common denominator among the three major countries in East Africa (Kenya, Uganda and Tanzania) is the perennial food shortages and malnutrition [15]. There is need to embrace livestock-fish culture integration systems to cushion the farmers from persistent poverty and hunger. The functional advantage of integrated aquaculture is conservation, reutilization of resources and low space requirements. For instance, the amount of organic matter which can be recycled in ponds as fertilizers is up to $5\text{g C m}^{-2}\text{d}^{-1}$, corresponding to $100\text{ kg of dry manure ha}^{-1}\text{ d}^{-1}$ [16].

Out of this, the expected production in a polyculture unit (common carp and silver carp) may reach 30 kg ha⁻¹ d⁻¹ without feeding the fish [16]. Such a yield is much higher than classical animal production on land [17]. Despite increased application of integrated livestock-fish farming worldwide, some shortcomings such as the transfer of diseases, high initial cost and special management skills needs have been reported [18].

Schematic flows of energy from one sector to the next in an integrated system are shown in Figure 1.

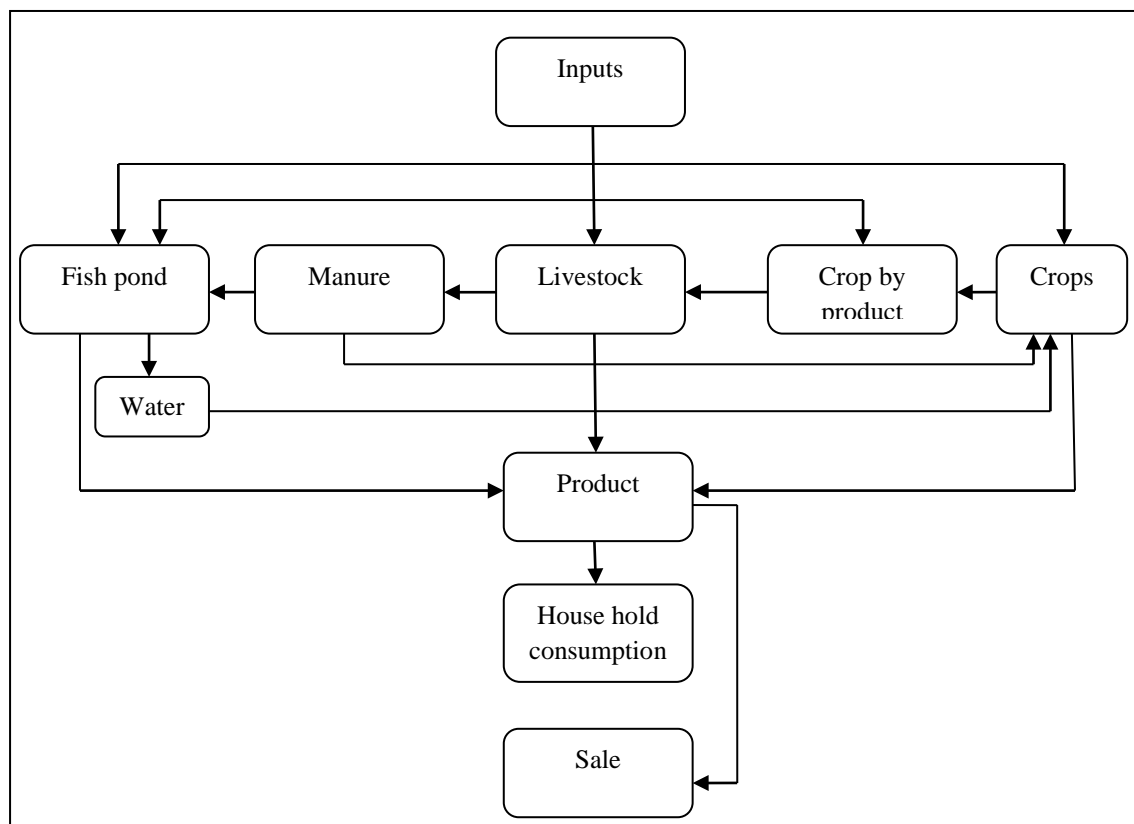


Figure 1: Schematic interactions between various subsystems in an integrated small scale agriculture-aquaculture system

Considering the economic and ecological contributions of integrated livestock-fish farming in other countries' rural economy, this paper critically appraises the potential of integrated livestock-fish farming (pig/fish, poultry/fish and cattle/fish) as a means of enhancing livelihood of every segment of the East African population. This paper discusses successful experiences in integrated livestock-fish culture in Asia and other African nations to encourage aquaculture stakeholders in the East African community to embrace integrated livestock-fish farming. It is hoped that the conclusions and recommendations presented here will be thought-provoking for a wide audience particularly policy makers, planners, NGOs, researchers and extension staff. It is

further hoped that the paper will stimulate actions to ensure that aquaculture development provides for reasonable rural livelihoods, a clean environment, and adequate food products.

Livelihood challenges in East Africa

Small scale farmers in developing countries are often poorer than the rest of the population, often getting less food to lead healthy lives [19]. Arresting poverty and hunger, therefore means confronting the problems that farmers face in their daily struggle for survival. East Africa with an estimated population of about 130 million is a fascinating region renowned for diversified natural resources including lakes, rivers, rainfall and good climate [19]. However, the majority of East Africans are still faced with threats of hunger and malnutrition [20]. East Africa's large rural populations depend mainly on rain-fed agriculture. Climatic hazards especially droughts have decreased production of staple crops, thus increasing pressure on water resources [21]. Human population pressure has caused land fragmentation therefore adoption of sustainable farming systems such as livestock-fish integrated culture is recommended [22]. Human poverty is the main obstacle to achieving economic and nutritional success in East Africa, while hunger and malnutrition remain amongst the most devastating problems facing developing countries [23]. Suggestions aimed at developing aquaculture in the East African region have emphasized intensive high-input systems rather than enhancing sustainable and improved traditional fish production techniques [24]. There is still a dearth of information on how to design integrated aquaculture systems, which are ecologically and economically sustainable in East Africa. Some major challenges of livestock-fish culture in the region include: lack of a comprehensive policy on aquaculture, poor information dissemination and technology transfer, low government funding, low investment by the private sector and incoherent promotion of aquaculture through many institutions including government, universities, research institutes, non-governmental organizations (NGOs) and other national authorities [25]. Inadequate effort has been put to strengthen the socio-economic sector of fisheries and aquaculture in the East African region [26]. Poor government priorities, illiteracy, limited publicity, strict cultural and religious doctrines are other bottlenecks facing livestock-fish culture in East Africa [26]. The communities bordering Lake Victoria have been reluctant to embrace fish farming activities despite declining fisheries stocks in the lake [26].

Status of integrated livestock-fish culture in East Africa

Uganda

Aquaculture sub-sector in Uganda has been described as a low-input, low-output undertaking [27]. However, aquaculture sector has grown over the last 5 years and many farmers are getting engaged through earthen ponds, cages and tanks [28]. Today, about 25,000 fish ponds covering 10,000 hectares producing 100,000 tonnes of whole fish annually has been reported [28]. However, the current status of integrated fish farming in Uganda is still at infancy stage and is largely undocumented [28]. Few farmers have demonstrated the potential of integrated

livestock-fish farming in parts of Uganda. For instance, polyculture of the African catfish (*Clarias gariepinus*) and the Nile Tilapia (*Oreochromis niloticus*) integrated with poultry and/or other livestock is common in Senya, Central Uganda where unpublished reports showed productivity of up to 3.7 tons ha⁻¹ year⁻¹ of *C. gariepinus* and *O. niloticus* (whole fish) [28, 29]. Despite enormous resources and great potential, the integrated livestock-fish farming has failed to take off due to social and economic challenges [30]. Integrated livestock-fish aquaculture is confined to remote villages by few poor farmers with little knowledge, whose work in most cases is unreported even in national aquaculture statistics [30]. In this regard, the authors recommend a special focus on the farmers through on-farm research and demonstrations, identifying and training farmers with leadership potential through formation of farmers' associations.

Kenya

In Kenya, livestock-fish culture is demonstrated by the state owned institutions like the Lake Basin Development Authority (LBDA) in Kisumu and the Kenya Marine and Fisheries Research Institute (KMFRI) in Sagana. A large number of farmers have embraced the practice across the country where they use mainly chicken and cow dung manure for pond fertilization [31]. However, there are no documented farming procedures and outputs of integrated-livestock fish culture in Kenya despite enormous potential. In Kisii, Kenya, integrated rabbit-fish farming has been initiated by few farmers [31]. However, there is no documented information showing the productivity potential and a lot of technical information is still lacking.

In 2009, the Kenyan Government funded a national fish farming program as part of efforts to promote fish farming, create employment and contribute towards reducing food insecurity in the country [32]. Unfortunately, no funds were allocated for the integrated livestock-fish farming despite its enormous potential. To date, some fish farmers have registered impressive performance in some parts of the country [32]. Furthermore, a few farmers have established integrated fish- poultry systems and have reported marginal returns despite the fact that the level of integration is still rudimentary [32]. Studies on integrated livestock-fish culture on the Kenyan side of the Lake Victoria Basin reported that a 200 m² fish pond of *O. niloticus* manured with cow dung provided an additional per capita fish supply of 3.4 kg to a household of 7 people and an average productivity of about 200 kg ha⁻¹ year⁻¹ [33]. Fertilization of nurseries and rearing ponds with cow dung is a widespread practice in Kenya and fresh cow dung from two cows is sufficient to fertilize 1 ha of pond area [33]. Such initiatives should be encouraged by the Ministry of Fisheries and research institutions. All stakeholders should promote integration of fish farming with other traditional cropping and livestock production systems. Need-based research should be prioritised.

Tanzania

Fish farming in most part of Tanzania is practiced as standalone activity, which can be a risky venture, because of economic factors such as the price instability [34]. Aquaculture in Tanzania began in the late 1950s with the pond culture of tilapia

species native to the region [35]. To date, it has not done any better. In the early 1970s, international donor funded projects were responsible for establishing an estimated 8,000 - 10,000 ponds producing about 2,000 tons of fish per year [35]. The number of fish ponds fell to less than 1,000 by 1985 due to poor management, inappropriate technologies, inadequate extension efforts, poor marketing and infrastructure [35, 36]. Despite a decline in pond tilapia production in Tanzania, livestock-fish culture is still viewed as a possible source of livelihood for farmers in the coastal region that is closer to the urban markets of Dar es Salaam [36]. The sector of integrated fish culture is largely neglected [37].

A comparison of growth performance of integrated fish pond (fertilized with manure and fed with vegetables) and non-integrated culture of tilapia was conducted in Tanzania. Results from the study showed that fish cultured under the integrated system exhibited higher growth rates than those in non-integrated systems (Figure 2). The observations were similar to other findings that integrated fish farming increases yield and produces fish based on the same land, water and labour [38]. Recently, a study conducted in Morogoro, Tanzania reported the use of livestock manures to fertilize Nile tilapia ponds by small scale farmers [39]. The farmers, however, realized low production due to unscheduled fertilization and improper feeding [39]. These systems should prove more attractive to the small scale fish farmers who are the majority in East Africa.

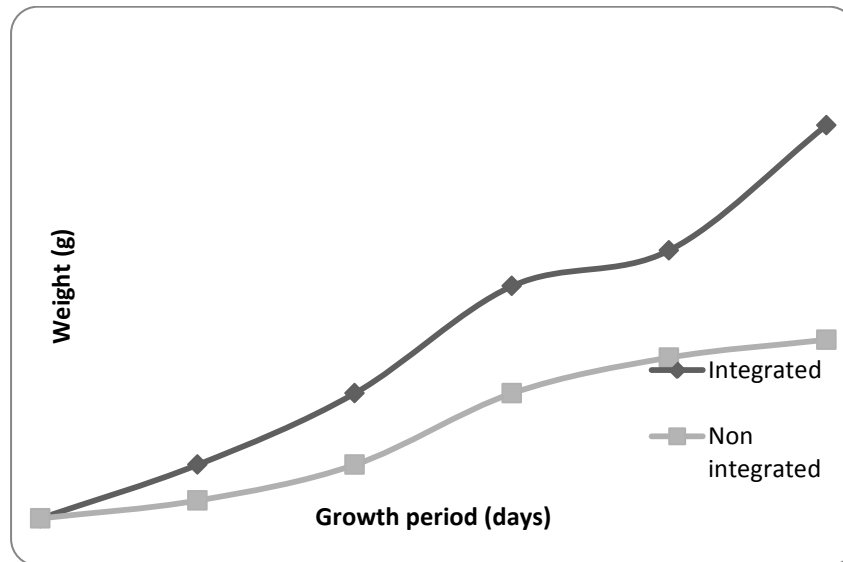


Figure 2: Growth trends of Nile tilapia reared under integrated and non-integrated systems in Tanzania [34]

Detailed analyses of integrated livestock-fish farming

Pig cum fish integrated culture

The pig is a highly prolific animal that easily feeds on cheap kitchen wastes and aquatic plants [40]. The excreta, which are nitrogen-rich, are used as organic manure in fish ponds [41]. In well managed pig-fish farming operations, whole fish production of 2 - 5 tons ha⁻¹ in 6 months and 4 - 5 tons ha⁻¹ in 6 months of pork was reported in Nigeria [41]. In addition, farmers practicing pig-fish farming have reported 28% - 30% economic advantage over normal pig farming [41, 42]. A successful case is integrated pig-fish-duck of Kafue Fisheries Company in Zambia with a total pond area of 37 ha producing 1.5 tons week⁻¹ of 180 - 250 g fish mostly indigenous tilapias (*Oreochromis andersonii*, *Oreochromis mossambicus*, *O. niloticus*, *C. gariepinus* and *Cyprinus carpio*) [43]. The main market for the fish is Lusaka (Zambian capital) at 3,000 Zambian Kwacha per kg, equivalent to US \$ 0.81 [43]. Monoculture of *Tilapia andersonii* with pigs yielded 7 tons of whole fish ha⁻¹ year⁻¹ in Zambia while monoculture of *C. gariepinus* with pigs yielded 7.5 tons of whole fish ha⁻¹ year⁻¹ in the Central Africa Republic with the growth rate of 2.9 g day⁻¹ for *C. gariepinus* [44]. Even though excreta of three pigs may just be sufficient to fertilize a pond of 1,000 m² in one production cycle, more than 30 pigs ha⁻¹ pond is recommended [45] to ensure sufficient supply of biofloc community for pond microbial synthesis and periphyton development [46]. Biofloc and periphyton also serve as additional food for fish [47]. Most of these promising examples of integrating fish with livestock are in countries within sub-Saharan Africa with similar climatic conditions to East Africa and, therefore, the same results can be achieved or even surpassed in East Africa if priority is given.

Poultry cum fish integrated farming

Birds reared for eggs (layers) or meat (broilers) can be integrated with fish farming to reduce the cost of inputs such as fertilizer and feed to maximize profits [48]. The poultry house can be raised over the pond (vertical integration) to minimise transport and maximizing land usage. The excreta from the birds serve as manure, which fertilizes the pond or the fish can feed on them directly [48]. Nutrient content of fish reared in chicken manure fed ponds is better than fish fed with pellet feeds [49]. Poultry manure is sufficient to raise tilapia from hatching to maturity [50]. A tilapia selection breeding program recorded highest growth response for tilapia under chicken manure alone compared to artificially fed tilapia [50].

In the Philippines, *O. niloticus*, common carp and snakeheads polyculture with broilers (stocked at 5,000 ha⁻¹), gave an estimated productivity of 7.3 tons of whole fish ha⁻¹ year⁻¹ [51]. In the Central African Republic, egg laying chicken (at a stocking density of 3,000 ha⁻¹) integrated with *O. niloticus* (30,000 fingerlings ha⁻¹), during a grow-out period of 189 days in 500 m² ponds, produced 5.5 tons of fish ha⁻¹ year⁻¹, plus 2,746 eggs year⁻¹ [52]. In another case, ponds stocked with *O. niloticus* (20,000 fingerlings ha⁻¹) and *C. gariepinus* (100 fingerlings ha⁻¹), combined with 1,500 Peking ducks ha⁻¹ produced 3.8 - 4.5 tons of fish ha⁻¹ year⁻¹ and up to 6 tons ha⁻¹ year⁻¹ (live

weight) of ducks [52]. In India, culture of common carps at a stocking density of 6,340 fingerlings ha⁻¹ integrated with ducks (100 ha⁻¹) yielded 4.3 tons of fish ha⁻¹ year⁻¹, 250 kg of ducks (live weight) and 1,835 eggs [53]. All these are promising results. However, the East African region needs to define relevant aspects applicable to the region.

As presently practised, the combination of duck and fish farming is considered as a means of reducing the cost of feed for ducks and an inexpensive way of fertilizing fish ponds. In this integrated system, ponds provide living and foraging areas for the ducks and fish. Hence, the rationale for integrated duck-fish culture is stronger than many other animal-fish systems [53]. However, ducks being 'manuring machines', they can cause eutrophication problems in the ponds [53] and feed on fish fingerlings leading to losses. It is important to provide adequate supplementary feeds to the ducks. Studies should be initiated to determine optimal number of animals to provide sufficient manure per unit pond area for optimal fish production. This will prevent farmers from either over or under-fertilizing their fish ponds. Table 1 below indicates the recommended number of animals and quantities of manure in integrated livestock-fish culture in Thailand [54]. There is need for the East African region to develop a locally fitting schedule.

Cattle cum fish integrated farming

Cattle are kept for beef and milk and for other benefits like hides and skins, labour for land preparation, transport and manure production. Fish farming can become more productive if it is integrated with cattle farming. Cattle graze on pond banks and grassy areas in the vicinity and manure is either collected or washed directly from the cattle sheds into the ponds [55]. This method helps to check land availability problems and reduces labour cost. Culture of Chinese carps in a pond manured with 15,000 kg ha⁻¹ year⁻¹ of cow dung, produced 5 tons ha⁻¹ year⁻¹ of whole fish [55]. However, cattle-fish integrated farming is not popular perhaps due to the high cost of rearing cattle [56]. East Africa is blessed with large herds of cattle. With the domestic markets for fish expanding, capture fisheries cannot meet the demand for fish therefore the widening supply and demand gap for fish. This offers growing opportunities for aquaculture production and this can be achieved faster through integrated fish farming [57, 58, 59].

Economic analysis of integrated fish farming

The economic benefit of integrated fish farming cannot be over-emphasized. It contributes immensely to the economic empowerment of many families especially in rural communities. It enables the farmer to be productive all the year round and fully maximize production as risks are evenly spread [59]. An analysis of economic returns from both integrated and non integrated tilapia farm in Tanzania revealed that an integrated farm gave higher economic returns compared to a non-integrated one (Table 2).

In the Philippines, a pig-fish farm sized 0.1 ha yielded a profit equivalent to Ksh 27,024 in six months (Table 3). Also, a fish-chicken farm sized 0.1 ha recorded profit equivalent to Ksh 20,245 in Bangladesh after six months (Table 4).

Conclusion and recommendations

Integrated livestock-fish farming approach as a biophysical and socio economic capsule has an immense potential to address income instability, nutritional insecurity, unemployment, and poverty of farmers in the larger East African community. Indeed integrated fish farming is inexpensive and profitable and could be the forgotten asset for present and future sustainable aquaculture development. The urgency in addressing issues of livelihood security, empowering rural poor through enhanced fish production process in an integrated manner in East Africa needs no further emphasis. Production yields from integrated fish farming vary depending on the livestock and the management system preferred. However, all cases of integrated fish culture have proved to be more profitable than unitary system of farming as it ensures the spread of financial risk. As an ecologically friendly activity characterised by reduced wastes, the ecological importance must be taken into consideration as this leads to aquaculture sustainability. In this regard, clear linkages between aquaculture and the environment must be defined and made known to all stakeholders. Studies are needed to optimize the production of the different integration components through closing nutrient circles in order to maximise benefits. Aquaculture promotion in the region should be more inclined to crop and animal husbandry than to fisheries, where it currently belongs. Similarly, specific policies tailored to integrated farming instead of unpractical, highly intensive aquaculture systems are recommended.

Table 1: Doses of manure required for maximum production in livestock-fish integrated systems in Thailand [54]

Animals	Animals/ha of fish pond	Fresh manure (Kg/adult/day)	Maximum manure (Kg/ha/day)
Pigs	30-3000	5 for 100kg pig	150
Chicken	1000-4000	0.15 for 1.5 kg bird	150-600
Ducks	750-3000	0.2 for 2 kg bird	150-600

Table 2: Economic comparison between Tilapia fish harvested from integrated and non-integrated culture systems in ponds in Tanzania [34]

Parameter	Integrated (USD)	Non-integrated (USD)
Gross revenue	20,770	2,694
Variable cost	12,775	3,389
Income above variable cost	7,995	0
Fixed cost	2,780	2,780
Total cost	14,773	6,170
Net return	5,996	0
Break-even yields (above variable cost)	8,296.46	2,200.84
Break-even yields (above total cost)	9,593.38	1,805.81
(kg/ha)		
Break-even price (above variable cost)	4.55	3.73
Break-even price (above total cost)	5.26	3.06

Table 3: Budget for fish-pig farming in 0.1 ha pond in Philippines. The costs have been converted to Kenya shillings [60]

Particulars	Cost in Kshs.
Fish culture	
Pond preparation with 15kg bleaching powder and 15kg urea at 8.56/kg	258
Fingerlings (850 at 250/1000)	439
Liming (25 kg at 2/kg)	103
Nets and labour for harvesting	824
Fish culture equipment	52
Pond rental	<u>619</u>
	<u>2,295</u>
Pig raising	
Pigsties	
Fattening of two lots of piglets for six months each	2,062
First lot weaned piglets	186
Pig feed (540 kg at 2/kg)	2,227
Second lot	2,413
Medicine	<u>82</u>
	<u>4,866</u>
Total cost	7,161
Interest on the working capital @15%	1,074
Total operational cost	8,236
Income	
Fish sale (600 kg at 20/kg)	24,744
Meat sale (300 kg live weight at 17/kg)	10,516
	35,260
Balance/profit	<u>27,024</u>

Table 4: Shows economic analysis of fish-chicken integrated farming/ha in Bangladesh. The costs have been converted to Kenya shillings [60]

Species	Number	%	Cost (Ksh)
Silver carp	400	40	80
Catla	100	10	100
Grass carp	50	5	50
Rui	150	15	30
Common carp	100	10	50
Sarputi	100	10	50
Mrigal	100	10	20
Total fingerling	1000		380
Running cost			500
Lime			200
Fertilizer: Cow dung			200
Urea			30
TSP			20
Netting charges			500
Pond rental cost			2,000
Fish total			3,830
Chicken section			
Chicken cost (105 birds)			10,500
Annual depreciation of chicken house			1,600
Feed (Ksh 8.5 /kg)			37,230
Labour			3,210
Chicken total			53,540
Contingencies			1000
Interest on working capital (12%)			6,885
Total Operating cost			64,255
Sales			
Sale of fish (550 kg × Ksh 35)			19,250
Sale of eggs (65% laying rate) (23,700 × 2.5* Ksh)			59,250
Sale of 100 hen			6,000
Total sale income			84,500
Net profit			20,245
Return on total operating cost (%)			31.5%

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