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Potential of integrated fish-poultry-vegetable farming system in mitigating nutritional insecurity at small scale farmer's level in East Wollega, Oromia, Ethiopia

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Abstract
Integrated poultry-fish-horticulture farming system is not practiced in Ethiopia but potential method of food production to mitigate problems facing vulnerable farmers in the country. The current trial was aimed to demonstrate and test the feasibility of the integrated farming system in East Wollega zone of Oromia region at a small scale farmers level. The farm was implemented at selected site based on basic research information. Productivity of the farm was compared against productivity reported in the basic research and the farmers practice. Potential to produce diversified food and generate income at small scale farmers level was evaluated. Productivity of the three components were found to be comparable to or better than the productivity obtained at basic research and farmers practice. Moreover, diversified products were produced on small area at a lower input cost in sustainable base. The local community accepted the practice as a technology. Government and other stakeholders have to support extension of the practice at applicable areas.

Keywords: integration, fish, nutritional insecurity, poultry, vegetable, waste recycle

1. Introduction

Ethiopia is a large country where food insecurity had been chronic with 44% of the population undernourished, 47% of children under five are underweight, and 52% stunted [1]. Though agriculture is a backbone of the country's economy with about 80% of the population involved in the business, productivity of the traditional farming is poor at farmers' level leading to food self-insufficiency. Productivity and sustainability of traditional rain fed agriculture at small scale farmers level has been challenged by recurrent drought in some parts of Ethiopia affecting the food and nutritional security goal of the country. Currently, nutritional insecurity of the population becomes a concern in many regions of the country. In spite of the situation, increasing productivity of the farms and diversifying their products are smart approaches to alleviate the nutritional insecurity problems. Aquaculture development, especially fish culture in ponds, is one of the potential techniques to achieve the nutritional security at household level in potential areas of the country.

World Fish production has raised by 167.2 million tonnes in 2014, of which aquaculture contributed to 73.8 million tonnes with an estimated first-sale value of US$160.2 billion [2]. However, though potential areas for fish pond culture are identified in Ethiopia [3], limitation in fish seed and feed supply hindered the development of fish culture in the country. Demand for fish is increasing especially during fasting seasons for Orthodox Christians [4] and fish culture can also be used as a source of income at a small scale farmers' level beyond the scope of nutritional security. The problem of fish feed faced in aquaculture development can be resolved by integrating fish farm with poultry [5, 6].

In the integrated farming of fish-poultry-vegetable, waste from one component is used as input for the next component. In this case, waste from poultry is used to fertilize fish pond substituting feed supplement for the fish, and nutrient rich water from fish pond is used to irrigate the Vegetable/horticulture crop during the water exchange for fish, substituting fertilizer use in crops. This technique recycles waste for food production and saves environment from pollution. Moreover, the technique saves production cost and is easy to manage at small scale farmers level. Integrated fish-poultry-horticulture production plays an important role in diversifying the farmers' products so as to improve diet of the people in developing nations like Ethiopia. The integrated production system diversifies income of farmers, create job opportunity for local people and contribute for household food security. The system maximizes productivity and economic efficiency of smallholder fish farmers through enhancing the productivity per unit area of land [7]. Few farmers in Oromia regional state started practicing extensive fish farming in small ponds using Nile tilapia since 2008 and the fish farmers were interested but not supported with a package to attain the potential production level [8]. Integrated farming of fish, poultry and vegetables has been experimented to be effective approach for sustainable production, income generation and employment opportunity for resource poor rural households [9,5,6]. The basic research works on the integrated poultry-fish-horticulture production system under local conditions was done by Batu fishery resources research center of Oromia agricultural research institute (IQQO). Following the information generated by the basic research, the technology has been demonstrated to small scale farmers in some zones of the region. The aim of this trial was therefore, to test and demonstrate the integrated fish-poultry-vegetable farming as a means of sustainable production system at small scale farmers level by diversifying their products, minimizing their input cost and increasing production per unit area.

2. Materials and methods

2.1 Descriptions of the area

The trail was conducted in Wayou Tuka district of East Wollega zone in Oromia region, Ethiopia. The site is 298 km from the capital Addis Ababa to the West on the way to Nekemt, situated in Farmers' Training Center (FTC) of Warababo Migna peasant association at $9^0$2'N and $36^0$40'E, at an altitude of 1910 m.a.s.l. The area is catagorized in to mid-altitude (locally known as Baddadaree) agro-ecology, receiving bi-modal type of rainfall with main rain from June to August. Production system of the area is mixed agriculture where the farmers produce field crops such as maize, wheat, barley and rear livestock such as cattle, goat, sheep and chicken all in traditional methods (data at local district offices).

2.2 Site selection for the technology

Factors affecting fish culture in pond, such as availability of year round water with the quality required by fish (optimum temperature and pH), site suitability for pond construction, horticulture and poultry management were considered. Accessibility of the site by the learning community was also considered. After checking the site to qualify the required criteria for the technology, discussions were made with government officials, community administrative, experts and local people. The site within Farmers Training Center (FTC) was selected for the technology transfer based on the interest of local community to learn the management of integrated fish-poultry-horticulture farming. As the technology is aimed to solve nutritional insecurity, the selected site was accessible for women, vulnerable households, youth and other local societies to easily learn the technology.

2.3 Fish pond construction and fish production

The three farming components, fish, poultry and vegetable were conducted in integration simultaneously by community participation. To conduct the trial, one rectangular shaped earthen pond having area of 15m X 10m ($150m^2$) and average depth of 1.30m with water inlet, outlet and overflow was excavated on a gentle slope land near to water source to secure the permanent water supply through gravity flow.

Before stocking the pond with the fishes, the bottom and the walls of the pond was treated with lime to kill potentially harmful microorganisms especially parasites. The lime also helps to increase the alkaline reserve in water and mud which prevents extreme changes in pH, neutralizes the harmful action of certain substances like sulfides and acids and promote biological productivity. Two weeks after liming, the pond was filled with water from the irrigation system via the supply canal. Poultry house in the integration was also stocked with pullets.

One month after poultry stocking, in May 2016, a total of 290 fishes fingerlings of three species (*Oreochromis niloticus, Cyprinus carpio and Claries gariepinus*) were collected from Batu Fishery and other Aquatic Life Research Center and Koka reservoir using beach seine hauls and stocked in to the pond under integration. The fishes were composed of 240 *O. niloticus*, 18 *C. carpio* and 32 *C.gariepinus fingerlings.* Tilapias were considered as the major product in the fish component of the integration whereby mixed sex tilapias of the best performing Chamo among the local strains were used in this trial. The fishes were managed properly by exchanging water regularly, removing impurities, protecting fish from predators and maintaining inlet and outlet pipes up to the end of harvesting period.

2.4 Poultry house construction and production

Poultry farming is one of the three major components of the integration. Poultry house construction is one of the main activity for establishing this integrated farm. The house having an area of 4m X 3m ($12m^2$), partitioned into two classes was constructed using locally prepared raw materials. The first class, half part of the house, 4m X 1.50m, was open to air enclosed by mesh wire around the poles and hanging over the pond while the second half part with sealed wall footing on the ground (fig 1b). The hanging class was used for the poultry to stay during day time where they eat and drink from hanged feeders and watering containers. Bottom of this class supporting the chicken was covered by stronger mesh wire protecting chicken against predators and competitors, allows poultry droppings passing down to the underneath pond water. The second class of the house footing on the ground serves for resting, night time stay and has nests for egg laying.

In this trial 30 pullets of Lohmann Brown breed were purchased from a commercial poultry producing company called Alema and stocked into the house and managed according to the companies recommendation. Commercial feed was provided to the chicken depending on their age, 80-110g pullets feed per day for 9-20 weeks pullet and 110-120g layers feed per day for the layers above 20weeks of age. All management including regular provision of feed and water, egg collection and health care were accomplished according to the recommendation of the company.

2.5 Vegetable production

Horticulture is the third component of the integrated farm. The plot selected for onion plantation was unfortunately degraded fallow plot. An area of $260m^2$ was cleared, ploughed and prepared for plantation. Before transplanting the seedlings of onion to the site, the plot was flood irrigated twice by water coming out of the fish pond in order to enhance the fertility of the plot. Onion (*Allium cepa*) variety called "Adama red" was used in the integration based on its higher market demand, higher yielding performance and better adaptation to the site. Seedlings of the onion was transplanted to the plot according to the local farmers' practice, with the recommended time and spacing. However, chemical fertilizers were not applied to the onion at all. Instead, the onion plot was irrigated regularly every 5-7 days by the fertile water coming out of the fish pond under the integration. Weed removing and cultivation activities were carried out every 2 weeks at earlier stages and by observing the weed appearance and intensity in later age.

2.6 Trainings on management of the integrated farm

Management of the integrated farm (poultry, fish and horticulture) was carried out by selected individuals from the local farmers after they received training on the component management. Local farmers participated in pond preparation, poultry house construction, land preparation for horticulture, and also attended the theoretical trainings. Lastly, the farmers attended fish harvesting practice and food preparation from fish on the final demonstration.

2.7 Data analysis

Data were collected by both primary and secondary methods. The primary data were collected from the trial site during the implementation of the technology. In addition to this, the primary data were collected by oral interview and product record sheet. The secondary data were collected from related research results, books, journals and agricultural offices.

Both qualitative and quantitative methods of data analysis were used. The qualitative data were presented by organized tables and narrations. The quantitative data were analyzed by using appropriate descriptive statistics like mean and percentages. Data generated from the various sources were presented as tables, figures or graphs.

Fish data for the parameters such as fish growth rate and survival rate (%) are calculated from initial number and weight (g) of stocked fishes, and final number and live-weight (g) of fish using the following formulas.

$$\text{Daily growth rate (DGR g/day)} = \frac{\text{Final weight (g)} - \text{Initial weight (g)}}{\text{Experimental days}}$$

$$\text{Survival rate(\%)} = \frac{(\text{Number of harvested fish} - \text{Number of dead fish})}{\text{Number of stocked fish}} X\ 100$$

The survival rate of the *O. niloticus, C. carpio and C. gariepinus* was analysed from the date of stocking to harvesting, during 381 culturing period.

3 Results and Discussions

3.1 Training

Some part of Wayu Tuka district is liable to climate change affecting productivity of their farms, leaving vulnerable households nutritionally insecure, especially their children. The nutritional insecurity problem of the area can be solved by increasing the productivity of the land, diversifying the farmers product in a sustainable way. Fish-poultry-horticulture integrated farming looks a simple and applicable candidate technology with this regard.

Initially, awareness was created to the local farmers on the benefit and use of the integrated farming system. Training (fig. 1a) was given to the beneficiary farmers on the technology before its implementation. The farmers then attended and participated in every activity of the farm during the component preparation; pond, poultry house and horticulture plot preparations. The integrated farm became the communal property of the beneficiary farmers where they learn the practice in the farming system and use the products for their own consumption and sell but keep every record as data.

The training covered 58 farmers, 8 development agents (DAs) and 4 fishery experts from potential districts in East Wollega zone on current status of fishery production with special focus to aquaculture development, criteria to be considered during site selection for aquaculture, pond design and construction, poultry house and onion land preparation, fish and pond management. In addition to this, trainings were given on how to harvest fish from pond, and how to process gutted and filleted fish and how to prepare food from fish in the form of soup, fried and boiled fish. Generally, subsequent trainings were given for the beneficiaries at each stage of production starting from the farm preparation up to the harvest and consumption of the products.

Fig 1: Training on the management of integrated farm, poultry house (b) integrated with fish pond, fish sample from the pond and eggs collected from the poultry.

3.2 Fish Production

There were three fish species, the Nile tilapia (*Oreochromis niloticus*), African catfish (*Clarias gariepinus*) and common carp (*Cyprinus carpio*) stocked into one pond as a poly culture under the integration system in May 2016. The number at stocking ware 240 tilapia, 32 catfish and 18 carps into a pond area of 150m^2 making a total fish density of 1.93 fish/m^2. The sizes of the fish at stocking were 29.13g, 44.69g and 53.86g for the tilapia, catfish and carp respectively (table 1). No supplementary feed was provided to the fish under integration throughout the culturing period. The fish were feeding upon the planktons and other organisms harbored in the integrated pond by the aid of poultry waste [5].

Waste recycling in the integration system was the Nobel idea concept. Poultry waste is either eaten directly by fish or fertilizes pond water to support the plankton community used by fish as natural organic feed [5]. Nutrient rich water from fish pond is used to grow horticulture being an organic fertilizer [6] and by-products from horticulture and fish offal being used as poultry feed to complete the loop in recycling.

Table 1: Summary of fish data in the integration

Parameters	*O. niloticus*	*C. gariepinus*	*C. carpio*	*total*
Number stocked	240	32	18	290
Average weight at stocking (g/fish)	29.13	44.69	53.86	32.38
Culture period	381	381	312	-
Average weight at harvest (g/fish)	275.3	1283.6	1305.7	437.2
DGR ($g.d^{-1}$)	0.65	3.25	4.01	-
Number harvested	237	32	13	282
Survival rate (%)	98.75	100	72.2	97.2
Actual yield/pond/culture period	65.25	41.08	16.97	123
Converted yield/ha/yr (kg)	4,167	2,623	1,323	8,113

At the end of the trial in 381 days, the *O.niloticus* - attained final body weight ranging from 144 to 442g with a mean of 275.3± 17.79g with mean daily growth rate of (DGR) $0.65g.day^{-1}$. The final average weight of male tilapias was 332.6 ± 16.53g while the females mean weight was 230.7±24.40g (Fig. 2). Different results on tilapia growth performance were reported by many authors. Negisho *et al.* [10] reported DGR of 0.57±0.01g with supplementary feed, which was less than the present study. Liti *et al.* [11] also reported varying DGR values (0.42 ±0.0; 0.52±0.04 and 0.68±0.04g) of Nile tilapia growth with supplement of different experimental feed in fertilized earthen ponds. In our current trial, the fish were depending on the recycling waste in the integration with minimal cost without providing any supplementary feed and chemical fertilizer. The fish growth rate in this trial ($0.65g.d^{-1}$) is close to the previous result of DGR 0.75g.d-1 reported by Endebu, *et al.* [5] in the integrated ponds.

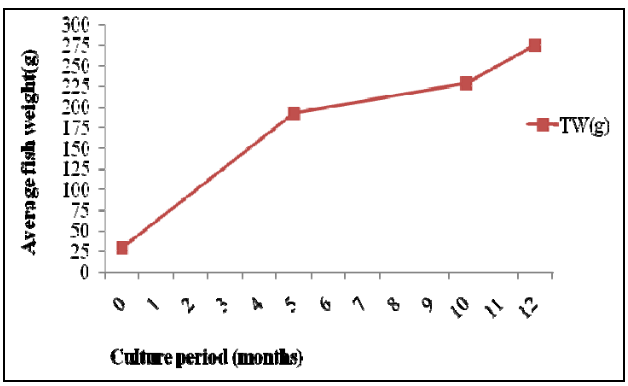

Fig 2: Growth performance of Nile tilapia in the integrated pond during the culture period.

C. gariepinus and *C. carpio* attained mean body weight of 1283.60±198.54g with DGR of 3.25g/d and 1305.70±48.30g with DGR of 4.01g/d in 381 and 312 culturing days respectively. The DGR of 4.01g/d attained by *C. carpio* in this trial was relatively on a better level compared to the 1.7g/d reported by Endebu *et.al.* [5] in fish-poultry integrated farm. The difference was attributed perhaps due to higher initial weight and longer culture period in the current trial. The current result recorded for the DGR of carp is comparable with $4.04g.d^{-1}$ reported by Abdelghany and Ahmad [12].

Integration of poultry with fish farm enhances planktons production and productivity in the ponds for the fish feed [5] thereby increased fish productivity in ponds. Supplementary feed was not provided for the fishes cultured in the pond integrated with poultry throughout the culture period. The fishes used the phytoplankton, zooplankton, direct feeding of poultry manure and spilled off poultry feed. The survival rates of the fishes, *O. niloticus*, *C. gariepinus* and *C. carpio* was 98.75%, 100% and 72.22% respectively.

Generally, a total of 123 kg fish was produced in the trial pond during the culture period at calculated yield rate of 8 tonnes of fish per hector per year. The contribution of fish as a protein source in securing nutritional balance of small scale farmers is valued.

3.3 Egg Production

The Lohmann brown pullets in the integrated farm started laying eggs two months after stocking in June 2016, at age of 22 weeks. After the egg production reach the peak in August 2016, it gradually decreased associated with age factor (Fig. 3). This result was similar to the result reported by Hirpo [6]. The production of egg decreases in later ages and becomes uneconomical after chickens reach the age of 18 months due to change in their physiology. Some irregularities and decline in egg production observed when the chicken were fed with homemade cracked grains during shortage of commercial feed supply. Availability of commercial feed for poultry at rural areas was limited that the government has to support feed producers to avail the feed at all areas demanding the feed.

Generally, 7,005 eggs were collected from the 30 layers in 12 months (Fig. 3). The collected eggs were sold by the beneficiary farmers to the local people at price rate of 2.5-2.75ETB per egg. The contribution of eggs as a protein source for the local people and the income from the selling to the beneficiary farmers are also valued.

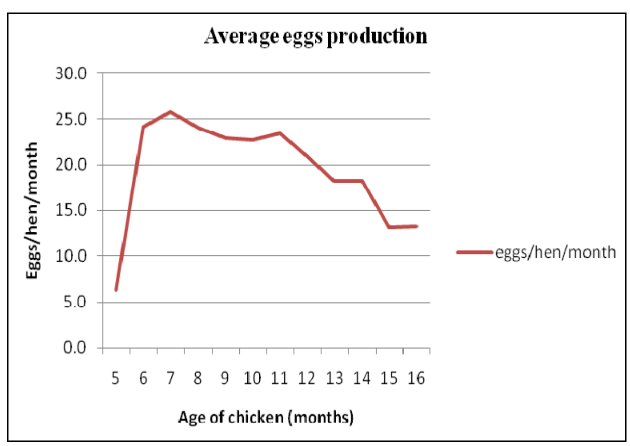

Fig 3: Average egg production per hen per month in the integration farm

3.4 Onion production

The product of Adama red onion (*Allium cepa*) grown in the plot (260m^2) integrated with the poultry and fish components was 281kg, estimated to 10,800kg/ha when extrapolated to hectare base. The obtained yield was ranked to a better production level when compared to the yield obtained using chemical fertilizers in some previous trials in Ethiopia [13].

The advantage of having horticulture component in the integration can be seen as alternative way of vegetable production for home consumption and also as a source of income, minimizing input cost and environmental pollution. The onion yield was obtained by using waste water from fish pond without purchasing the chemical fertilizer, which minimized input cost in the production system. The system also minimized environmental pollution caused by waste from poultry farm and fish pond, rather recycled the waste to produce food.

3.5 Partial budget analysis

Simple calculation was made to know the economic feasibility of the integrated farm comparing input costs against outputs in money value. Labor costs were estimated though the workers were not paid for the little activities they performed in the farm. The poultry house and fish pond construction works were done by beneficiary farmers while they participate in all stages of the technology implementation, but the value was estimated in terms of money (table 2). Depreciation values of the poultry house and fish pond were considered in production costs.

The products from the integration were used for local consumption after they were estimated in terms of money. Revenue generated from the selling of eggs, fish and onion (table 2) was used. The hens and equipments were also estimated for their current value in terms of money at the end of the trial for financial analysis.

Table 2: Partial budget analysis of fish, egg and onion production

	Fish			
Production cost	amount (ETB)		Revenue generated from fish	amount (birr)
Fingerling purchase (variable)	870		Fish selling 25 birr x 282	7,050
Estimated labor cost	600		Total profit (revenue-cost)	4,880
Fishing net depreciation	300			
Pond depreciation cost	400			
Total cost in fish component	2,170			
	Poultry			
Production cost	amount (birr)		Revenue generated from poultry	amount (birr)
Pullets purchasing	2700		revenue from egg production	18,160
Poultry feed purchase	8600		Estimated value of poultry at the end of the trial	2,100
Poultry feeders & equipment	480		Estimated value of equipments	120
Estimated labor cost	1800		Total revenue from poultry	20,380
Poultry house depreciation	800		Total profit in poultry	6,000
Total cost in poultry	14,380			
	Vegetable			
Production cost	amount (birr)		Revenue generated	amount (birr)
Estimated cost for land preparation, weeding, etc	600		Selling of onion (280*8ETB)	2,240
Purchase of onion seedling	400		Profit in vegetable	1,150
Purchase of pesticide	90			
Total cost	1,090		Total profit in the system	12,030

Total land area occupied by the integration system was less than 500m^2 (0.05ha). This plot, according to information from the local farmers on their practice, can yield 250-500kg maize per year, which is estimated to a total amount in money of 1250-2,500ETB at current price. Though the farmers do not consider the labor of land preparation, cultivation, weeding and harvesting as a cost, it can be estimated to 1200ETB to produce maize in the plot. The profit farmers expect from that small plot of land according to their traditional practice do not exceed 1,300ETB per year under conducive weather conditions. This traditional way of production is efficient (about 52% return on their initial investment) but produce little product per unit area and risky as it depends on natural rain.

In the present integrated farming system, the total estimated cost of production in the fish, poultry and vegetable components was 2,170ETB, 14,380ETB and 1,090ETB respectively with a total estimated production cost of 17,640ETB. The revenue obtained from all harvested fish was estimated to 7,050ETB while the revenue generated from poultry and onion production was 20,380 and 2,240ETB respectively. A total of 29,670ETB was generated as revenue. The profit obtained from the three components sum up to 12,030ETB (table 2). The highest profit was obtained from egg and fish production. The integration of fish, poultry and horticulture farming is also promising technology to generate income for household on a small plot of land having access to water source.

The technology was finally demonstrated to the local community and government officials at different administrative levels. The beneficiary farmers, local communities and administrative bodies understood the benefits of the integrated farming system in terms of its sustainability, contribution to food & nutritional security, income generation, poverty reduction, easiness of the farm to be managed by women, children, hand caped and old people. It was finally accepted as a technology to be extended.

4 Conclusion and recommendation

In the integrated poultry-fish-vegetable farming system, waste from one component is used as input for the other component in the system to produce food for people. The system worked at the trial site with all the components (poultry, fish and vegetable) delivering the expected products at lower costs of inputs on relatively small plot of land as compared to the traditional farming system. Products obtained from the integration diversified the farmers' produces with protein rich commodities which gears towards nutritional security on a sustainable base. Moreover, the system is cost effective and efficient enough to make money at small scale farmers level on relatively small plot of land.

The technology is also a very good resilience approach to produce sustainable food for victimized farmers of climate change in areas having access to water sources. As the fish culture in general and the integration system in particular is new practice in Ethiopia, attention should be given by local administrative bodies, regional and federal governments and concerned institutions to extend the technology into potential areas.

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