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# Status of integrated aquaculture - Agriculture systems in Africa

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**Abstract**
Demand for animal derived protein source is increasing owing to the increase in human population throughout the world. Agriculture which is the major source of animal protein for the world is now facing challenges owing to scarcity of adequate land and water. As demand of water to industries and household are increasing, the share of water for agriculture production is substantially decreasing particularly in arid and semi - arid zones. Thus, there is need to develop viable technologies which can sustain production. It is in this context integrated rearing system has been proposed amongst the potential alternatives. In this context the principle of integrated fish - livestock and fish - crop farming involves rearing fish besides with livestock and crop production. These systems are especially relevant for developing countries since there is limited capacity of the farming community for intensive fed aquaculture. Socio - economic assessment on integrated aquaculture-agriculture systems in the Malawi, Ethiopia and Nigeria have showed promising results towards combating poverty and malnutrition. Thus, the emphasis in this review is centered on compiling research and development outputs in integrated aquaculture –agriculture systems in the past few decades with an anticipation of providing information for policy makers to help make evidence based decision making.

**Keywords:** aquaculture, integrated farming systems, nutrient recycling, agriculture

## 1. Introduction
Demand for animal protein is increasing due to a higher population growth throughout the world [14, 6]. Agriculture which is the main source of animal derived protein for the world is facing challenges of land scarcity and water shortage [61, 65, 54]. On the other hand, our planet comprises more than 75% water ecosystem which is in most cases neglected in terms of production. Therefore, it was found important to support the agricultural sector with aquaculture which is the farming of aquatic plants and animals with some kind of involvement in the production process. Moreover, agriculture is the biggest consumer of water in the world [3]. However, since the demand of water to industries and house hold increases steadily the stoke of water for agriculture production is considerably decreasing. In this case, increasing productivity of water through varied farming systems have been proposed as amongst the potential alternatives currently employed [59, 1, 57, 3, 62, 22, 23]. Integrated farming system is the linking of the different components of farming systems to each other to attain synergisms in which an output from one farming system is used as an input to the other farming system resulting in efficient water and land usage [13, 29, 7]. Integrated agriculture - aquaculture systems provides also a continuous source of income from the different components of the system [4]. These systems are self-sustaining and less input systems where the waste from one system which was otherwise wasted is used as an input to the other system. In this context the principle of integrated fish - livestock and fish - crop farming involves rearing fish besides with livestock and crop production. This sort of farming system gives great efficiency of resource utilization and efficient exploitation of available farming space for increasing production per unit area [31, 18, 47, 29, 44, 10, 37]. The rising cost of production of fish, chemical fertilizers and available space are the main derivers of the system. The combination of fish culture with crop production and animal husbandry is an environmentally sound farming system which gives inexpensive source of protein for the rural people, a better farm income and increased output per small land area and increases the supply of feeds for the livestock farming system. The scope of integrated farming system is significantly wide based on the farming systems of different societies. According to [15] geese and ducks are raised around

ponds where the dykes of the pond are used for agricultural and horticultural crop products and animal farming. A socio – economic assessment survey conducted by [4] indicated that, integrating aquaculture with the existing farming systems resulted in promising results although there were various constraints. The objectives of this paper is thus to review relevant literatures on the variability of the systems and their economic feasibility in few selected African countries.

## 2. Discussion
### 2.1 Livestock - fish integrated systems
Integrated farming systems can be classified broadly into two categories i.e. crop-fish systems and livestock-fish systems [15]. The main possible links between fish and livestock production are usage of nutrients especially the re-application of livestock manures for fish production [29]. This re-application is aimed mainly at supplying nutrients like nitrogen (N) and phosphorus (P) which are the precursors of the primary production in fish ponds. On the other hand, there are also applications aimed at direct feeding of animal wastes by carnivorous and detritus feeding fishes although not popular [13]. Although there are few pre-processing of animal wastes before application, direct uses of animal manure, urine and spilled feed is the most practiced and widespread application system [47]. Livestock-fish integrated systems mainly consisted of duck - fish, Poultry - fish, Pig - fish goat - fish, rabbit - fish and cattle - fish systems [15, 24, 5]. An eco-energetic analysis of the above mentioned systems in the northern Himalayan part of India was analyzed by [5]. The results from this study showed that the highest nutrient input (Nitrogen and Phosphorus) was in the poultry – fish system of integration followed by cattle dung - fish system. The same study also found that the annual energy input of all the integrated systems was higher than the non - integrated fish production systems. The fish yield was also by far greater in the integrated systems than in the non-integrated ones. This study was in confirmation with [50] for the duck - fish integrated system where the fish yield exceeded by 8 tonnes ha-1 from the non-integrated system. On another study by [20] comparison of applications of chicken manure, cattle manure and pig dung on unfertilized fish ponds was conducted. The ponds with the applications of chicken manure showed the highest growth rate and higher annual yields than the other systems and the non-manure treated cultures. In addition, the contents of organic matter and chlorophyll *a* were also significantly higher in manure administered ponds than the non-manure treatments [20, 42]. Generally fish and livestock integration is trending in many countries throughout the world and the income has been found to be higher than to the elite fish production [15]. Moreover, livestock fish integrated farming systems provide an opportunity for waste disposal which otherwise spoils the environment. On the other hand, recent trends in the livestock-fish integration systems have been the addition of a third component which is vegetable production using the effluent from the system [35, 9, 12].

**Table 1:** Summary of the production trends in integrated livestock –fish – vegetable systems in Africa

| Country | Pond size ($m^2$) | Components of the integration | | | Major findings | References |
|---|---|---|---|---|---|---|
| | | Fish species | Livestock species | Vegetable variety | | |
| South Africa | Two 200$m^2$ | Common carp<br>Bighead carp<br>Silver carp<br>Grass carp | Pecking ducks | Tomato<br>Spinach<br>Lettuce | • Ducks grew to an average weight of 2.6kg in 55 days<br>• Fish production exceeded 19.5tonnes/hectare/year Substantial yield of vegetable production<br>• Ten batches of Peking ducks at a density of 2 500 ducks/ha of water over a period of 6 months with an average yield of 32.184 tons/ha/year<br>• Mean FCR of 3.05. | [50] |
| | 30$m^3$ | | Muscovy Ducks and pecking ducks | Cabbage<br>Spinach<br>Beetroot | • Possible to produce a minimum of ten cycles of Peking and seven cycles of Muscovy ducks/year.<br>• 1670 kg of live mass of ducks per 150 $m^2$ pond space.<br>• This amounts to 111 tons of Peking ducks or 59 tons of Muscovy ducks per ha of pond water. | [49] |
| Malawi | 20 | *Tilapia rendalli* | Chicken<br>cattle<br>pig manure | - | • After 84 days the *T. rendalli* in the chicken manure treatment were significantly larger and had higher net annual yields than those in the cattle manure, pig manure and no manure treatments.<br>• Chicken manure treatment gave significantly higher amounts of chlorophyll a and higher numbers of zooplankton | [20] |
| | - | - | - | - | The assessment by the authors indicated that The IAA farm families have achieved a range of benefits including<br>• Increased farm productivity, increased household incomes, improved adaptation and resilience to erratic climatic conditions; improved food and nutritional security through increased production and consumption of fresh fish and food crops grown around the fish ponds. | [38] |
| | - | - | - | - | • Assessing a technical ineffectiveness function shows that IAA farms were significantly more | [11] |

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| | | | | | efficient compared to non IAA farms.<br>• IAA farms also had higher total factor productivity, higher farm income per hectare, and higher returns to family labor. | |
| | - | - | - | - | • By 2004 there were over 7,000 small-scale IAA adopters in Malawi<br>• In Cameroon, the number of small-scale farmers involved in IAA increased from 15 to 137 over the course of the 2000–2005<br>• The 7,000 small IAA farms in Malawi have a combined total of 186ha in pond surface area, an average 275m$^2$ per farm.<br>• Cameroon has only 300–400 IAA farms<br>• Mozambique had just over 3500 small backyard earthen ponds ranging from 100 to 400m$^2$<br>• The 6,400 IAA farms in Zambia have a collective total of 155ha of pond with an average per farm area of 242m$^2$. | [51] |
| | - | - | - | - | • Although Chingale has over 18 crop varieties and 5 livestock species that have potential for integration into the farming system, only 33% of the sampled farmers were integrating over 5 species (both crop and animal species) in agriculture systems resulting in low economic efficiency, low incomes to the farmers and low sustainability of farming systems. | [39] |
| Ethiopia | - | *O.niloticus* | 20 White leghorn egg lying chicken | - | • The NPV of the project at 8.5% of discount rate (Commercial Bank of Ethiopian, 2011) was found to be Birr 27,267/ha of land which is acceptable in terms of feasibility. | [35] |
| | Two ponds with 6x8 dimensions | *O. niloticus, C. carpio C.gariepinus* | 15 layers of Rhode Island Red chicken and goats manure | - | • Zooplankton abundance- rotifers > 10individuals/ml in poultry manure fertilized ponds while less abundance of rotifers was observed in goat manure fertilized ponds<br>• In terms of fish growth the poultry manured ponds gave significantly better growth in both *O. niloticus* and *C. carpio* species | [32] |
| | 150 | *O.niloticus* | 25 White leghorn chicken | Onion (*Red bombey*), cabbage (*Vikima*) tomato (*ROMA VFN*) | • The partial budget analysis of the integrated farming indicates that the estimated net profit obtained on 1ha of land was 37344 Eth Birr (1 Birr = 0.044 USD).<br>• However, the net profits from a common crop in the area (maize), fish, chicken and vegetables alone were 2, 9, 18.2 and 72.8 % of the net profit obtained from the integrated system. | [12] |
| | 150 | *O. niloticus, C. carpio and C.gariepinus* | 30 pullets of *Lohman brown* chicken | Onion (*Allium cepa*) "Adama red" variety | • Total profit from the integrated system was 12030ETB while the profit farmers get from the sole maize production from the same plot of land was 1300ETB<br>• 8 tons of fish/ha/year, 233eggs/hen/year, 10800kg onion/ha/year | [9] |
| | 200 | *O.niloticus* | Poultry Cow | Tomato (Cochoro variety) and onion (Bombay red) | • The authors reported that<br>• Water physico-chemical parameters remained within the required level for the growth of Nile tilapia.<br>• Higher level of nitrate and total phosphorus in the IAA ponds<br>• Comparatively higher level of soil organic carbon and organic matter in the IAA ponds than the non-IAA ponds<br>• Higher number of tomato fruit and bigger size in the IAA plots.<br>• Higher yield of onion from the IAA plots than the control plots<br>• The results on the analysis of expenditure and income indicated that the integration of vegetable cultivation using fish pond water alone was more profitable than the conventional method of vegetable cultivation with the application of fertilizer. | [64] |
| | 72 | *O.niloticus* | Rhode Island Red | Bombe red onion (*Allium cepa*), Malkashola | • The author reported<br>• *Brassica oleracea* - 221 q/ha for the IAA while 98 q/ha for non IAA system<br>• *Allium cepa*- 371q/ha for the IAA while 165 | [25] |

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| | | | | Tomato (*Lycopersicon esculentum*) Cabbage (*Brassica oleracea*) | q/ha for non IAA system<br>• *Lycopersicon esculentum* - 458q/ha for the IAA while 171 q/ha for non IAA system<br>• Higher production of the integrated systems as compared to the non-integrated ones.<br>• Significantly improved fish production due to the presence of poultry manure and wastes in water that served as fertilizer for horticultural production. | |
| Kenya | - | - | - | - | Farms with IAA systems were found to have<br>• A drop by 23–35% of nutrient depletion rates<br>• increased by 2–26% of agricultural production and<br>• an increased by 22–70% of the overall farm food production | [37] |

### 2.2 Crop - Fish Integrated Systems

Crop - fish integrated systems includes rice integrated with fish system, horticulture integrated with fish system, sericulture integrated with fish system and mushroom integrated with fish system [15, 8, 58 2, 28, 53, 30]. In this context, applications of integrated crop production and fish production are aimed mainly at disposing aquaculture effluents and providing organic fertilizers to agricultural crops [55, 8, and 30]. This is especially very important in arid and semi- arid areas where water for irrigation is limited. Nutrients from fish effluent are also an important substitution for commercial fertilizers in which the low income farmers cannot afford to buy and apply to their crop land. In this context, [8] demonstrated that it is possible to increase the yield of cherry tomato by using fish effluents to irrigate. The other system important to mention is that of rice - fish integrated systems. Rice - fish integration is a long time practice. The existence of fish, snail, mussels, frogs and prawns in rice paddies is natural. The integration of fish in the rice paddy field system associates through feeding of fish on the zooplankton and weeds and stirring of the sediments which leads to nutrient re-suspension [46, 34]. In relation to pest management, [63] described that a polyculture of Thai silver barb, common carp and Nile tilapia was able to reduce the number of larvae of rice caseworm *(Nymphula depunctalis (Guenee))* by 93%. It has been observed that the incorporation of fish in rice fields resulted in an increase in rice yield [34]. Potential fin fish species which can be reared in rice fields ought to be species which are accustomed to low dissolved oxygen levels, high water turbidity, surface water and higher temperatures. According to [15] report, finfish species such as *Clarious batrachus, Clarias macrocephalus, Anabas testudineus, Mugil species, Catla catla, Cirrhina mrigala, Labeo rohita, Cyprinus carpio, Oreochromis mossambicus, Lates calcarifer, Channa striatus, Chanos chanos and Channa marulius* have been cultured along with the rice fields. Often in some countries integration of crop - livestock - fish systems is being practiced in which livestock wastes are directed to fish ponds where the wastes fertilize the pond water. Subsequently the fertilized pond effluent is used to irrigate the nearby crop fields [48, 49].

### 2.3 Integrated Multitrophic Aquaculture (IMTA)

Integrated multitrophic aquaculture is a concept in recycling of resources in which discharged nutrients from higher trophic levels become input to the lower trophic levels [40,19]. IMTA is a system used to mitigate the effects of intensive finfish culture on the environment by employing extractive aquatic species in the vicinity of the systems. Seaweeds and abalone [41] sea cucumber [40] and Mussels [19] are among the aquatic species which are being used as an extractive species in IMTA. This system is mainly practiced in developed countries where there is an intensive cage culture of finfishes like salmon [16]. On the other hand, integration of intensive and extensive aquaculture systems in a form of a combined pond aquaculture is also being practiced. This system proves to enhance the nutrient utilization and fish production [10]. The system resulted in higher protein utilization up to 26%. In another study by [66] described that the integration of intensive hybrid catfish culture and semi-intensive Nile tilapia culture showed that significantly higher nutrient recovery of Nile tilapia was observed from the intensive cultures of catfish. Integration of aquaculture also takes the form of polyculture in which fish species of different feeding habit and niche are being cultured in one system. This system allows efficient resource utilization in the system and reduces the effect of fish effluents to the environment. The best example of such a system is the production of different carp species in one system [21, 56, 45]. Integration of the fish species such as silver carp, common carp and bighead carp resulted in a four times

**Table 2:** Summary of the production trends in integrated crop –fish systems in Africa

| Country | Area ($m^2$) | Components of the integration | | | Major findings | References |
|---|---|---|---|---|---|---|
| | | Fish species | Crop variety | Vegetable variety | | |
| Nigeria | | - | - | - | The authors identified that the major challenges for the under development of the IAA system in Nigeria were<br>• ground water availability, capital, unavailability of high quality, fingerlings, sources of information, government policy, access to extension services, soil and water, availability of land, cooperative society, credit subsidies, input subsidies and access to information | [43, 67] |
| | | *C.gariepinus* | Yam Maize Cassava | - | The author found that<br>• net return on investment of the crop fish integrated systems exceed by 0.5 factor from the sole crop and fish production indicating the profitability of the IAA systems | [60] |
| | - | Nile tilapia | Rice | - | Rice-fish trials in Niger State used a local swamp/lowland rice variety (FARO15) integrated with Nile tilapia (*Oreochromis niloticus)* over a | |

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| | | | | | four month production period results indicate<br>• A ten percent increase in rice yield and more than 50 percent increase in revenue due to income from rice and fish.<br>• Clearly, development of the commercial aquaculture industry and inland fisheries remain the best solutions for increasing domestic fish production and meeting the large demand for fish. | [33] |
| Ethiopia | 542 | *O.niloticus* | Rice | - | The authors reported<br>• A decrease in the dissolved nutrients like nitrate and phosphate in the water from the initial level in the paddy-fish plots.<br>• Reduced soil nitrogen with respect to the increase in phosphorus levels.<br>• Higher plankton and benthic population in the control plots than in the paddy- fish plots<br>• An increase in silt fraction, organic carbon and organic matter in all the plots.<br>• Higher yield of rice in the paddy-fish plot than in the control plots | [27] |
| | 400 | *O.niloticus* | Rice | - | • The yield of paddy grain and plant biomass was higher in the paddy-fish integrated plots (112.3 kg) than the control (95.65 kg).<br>• A total of 218 fishes of marketable size were harvested mean total length and weight of the fish was 17.5 cm and 193.15 g respectively.<br>• The results of the study proved that paddy and fish integrated farming is more profitable for small scale farmers in the lowland areas of Ethiopia. | [26] |
| | 350 | *O.niloticus* | Rice | - | The results showed that<br>• On the two rice fields, 720kg/ha and 1500kg/ha can be harvested through integrated rice and fish culture. | [36] |
| Kenya | 915 | *O.niloticus* | Rice | - | • An average fish production of 132.4 kg/ha was obtained.<br>• The mean recovery rate of tilapia was 43 per cent.<br>• Total rice yield from the fields stocked with fish was lower than from non-stocked fields. | [52] |

higher production over single species culture [17]. Cultivating different carp species in one pond is a great interest not only for efficient resource deployment but also in respect to the exploitation of all the environmental spaces existing in the pond ecosystem [21]. Common carp is a bottom dweller with omnivorous feeding habit where by consuming detritus and benthic zooplankton, whereas, silver carp is a surface dweller with a feeding habit of macrophytes. On the other hand, bighead carp is a mid-water dweller with a feeding habit of pelagic zooplanktons suspended in the water column.

## 3. Conclusion

Despite the huge potential in the continent, aquaculture production in Africa remained low. In order to realize this This in turn contributes to the protection of the environment by recycling resources which could otherwise be wasted. Research should redirect the focus also towards sustainability of aquaculture without disregarding the environmental impacts due to intensive fed aquacultures

potential, redirecting the focus towards aquaculture development is necessary. Diversified aquaculture resources and suitable environment makes aquaculture a huge potential in the continent. However, under exploitation and poor utilization of these resources gives Africa the name " The sleeping Beauty" by other developed nations. African farmers have low capital in order to intensify aquaculture production. However, integrated aquaculture with the existing farming systems could solve this problem and provide additional income for the betterment of farmer's livelihood. These integrated systems may avoid the constraints imposed because of high capital requirement for intensive fed aquaculture. Moreover, the presence of diversified agricultural activities among African farmers could help to realize this potential.

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