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Ideas matter: Using aquaculture technology to enhance smart farming in Lira city, mid-north Uganda

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Abstract: **This study aimed to determine how adoption of aquaculture can translate into smart farming among urban farmers in Lira city. A descriptive study design was adopted targeting only one fish farm in the city and data was collected using interviews and observations were used as well as reviews of secondary data which were used at the introductory party of this work. Questions were asked to the farm manager and the director who later joined us during the questions and answers session; and analysed thematically. The findings show that the three aspects of aquaculture, namely; the hatchery where eggs are extracted and hatched, water production used to sustain the pond and the fish inside, and the pond security have a greater potential of enhancing smart farming among urban farmers in Lira city and the country as a whole. Nevertheless, adoption of aquaculture is yet to be embraced by a good number of urban farmers, something likely to derail the country from attaining adequate nutrients as well as tapping into both local and regional fish markets. The outcomes of this study may be used by urban authorities and the line ministry to develop guidelines for engaging smallholder urban farmers more aggressively into the enterprise as well as conserving the environment. This paper contributes to the growing both of knowledge by underscoring one of the affordable smart farming technologies that can be adopted create self-employment, better nutrition and food security in the region.**

Keywords: **Smart farming, aquaculture, hatchery, water, pond.**

1. INTRODUCTION

Trained Apiary Farmers (TAF) Assured Mixed Enterprises is an agri-tourism farm, was started in the year 2008 at Ngetta Sub-county, Lira district (now Ngetta ward, Lira City East Division-Lira City) basically as beekeeping, fruit production, and mixed farming project. Tom Anyii Okello, the Managing Director of TAF recounts how he started the farm with only eight local beehives before being supported by the National Agricultural Advisory Services (NAADS), hence acquiring up to 200 hives by 2011 when the enterprise finally got registered with the government as a community-based organization (CBO) to provide skills, knowledge, materials, market and to add value to agricultural products.

The idea of starting a farm was conceived in 2007 when he attended a motivational and life-changing training on economic management and transformation at the National Leadership Institute (NALI) Kyankwanzi. Anyii adds that this training which was organized for sub-county chiefs across the country was conducted by the Ministry of Finance Planning and Economic Development to empower leaders with skills and the right attitude to cause economic transformation and prosperity in the villages. After being motivated, Anyii later opened his farming enterprise on a four-hectare piece of customary land but later expanded the farm by acquiring other nearby land and now operates his farming business on 12 hectares of land all located in the same cell.

Since then, Trained Apiary Farmers (TAF) Assured Mixed Enterprises have ventured into poultry farming, rabbit rearing, citrus farming, and piggery alongside apiary or beekeeping which was the first enterprise of the farm and fish farming (aquaculture) which will be the basis of this discussion. Fish farming came on board after a visit by Anyii to the Netherlands where he reportedly saw several fish farms. "I started fish farming as a result of excitement. When I went to the Netherlands, I found people keeping fish under their beds, under the verandas, in the compound as well as in containers in their living rooms! This rather weird fish farming appetite of the landless people in the Netherlands ended up motivating me to venture into aquaculture" Anyii explained. When he returned, he constructed three fish ponds to start his fish farming venture.

Stickney, R. (2000) describes aquaculture as the rearing of controlled organisms under controlled or semi-controlled conditions. This may include rearing of aquatic plants and animals with the objectives of providing food, recreational fishing, enhancement of commercially valuable stocks, recovery of endangered species, and the production of baits and ornamental species. Available research suggests that aquaculture contributes up to 43 % of aquatic animal food for human consumption in the year 2007, but it is also recorded that the more globalizing trend of trade and favourable economics of large scale intensive farming have encouraged the increasing production of carnivorous fish species like catfish, salmon fish and shrimp among others. However, it should also be noted that some farmers breed in their ponds these carnivorous species to regulate the population of the wanted fish being bred for economic reasons and consumption, this is because some species like the Tilapia in Uganda can multiply very fast and overpopulate the pond they are being raised in.

By 2008, over 50 years, the global aquaculture production had astronomically grown to around 52.5 million tons, equivalent to 68.3 million including aquatic plants worth US$98.5 billion and US$106 billion including aquatic plants and accounting for over 50% of the world's fish food supply. In this production statistics, Asia dominates this with 89 % by volume and 79 % by value where China remains the largest producer accounting for a lion's share of 32.7 million tons in 2008. When there was a 5.2 % growth in China, it represented a 52.3 % increase in global aquaculture supply for 2007. China's closest challenger was Vietnam which contributed 17.7% of aquaculture production presenting a growth rate of 0.1%. Over the years there has been a steady increase in the aquaculture production where growth was at 6.9% per annum for the period between 1970 to 2006 with a slight slowdown for the period 2004 to 2008 when it averaged 5.8% (FAO 2009*a*). The development of aquaculture in North America and Europe was fast between the 1980s-1990s but this has since stagnated as a result of restrictive regulatory regimes and other competitive factors. According to (FAO, 2009b), the average annual growth of aquaculture production over five years, calculated using the difference between mean values from the period 200-2002and 2005-2007detected a constant rate.

Fiskeridirektoratet (2008) notes that by 2008, approximately 60% of the world's aquaculture production (56% by value) was produced in freshwaters even though freshwaters constitute only 3% of the planet's waters and 0.3% of that being surface water. Of the 60% fish production, 65.9% were carp and other cyprinids which are mostly cultured in ponds using semi-intensive methods (water fertilization with inorganic and organic fertilizers and supplementary feeding with low protein materials). Salmonid farming (mainly rainbow trout in freshwater) constituted only 1.5%, mainly using ponds, concrete raceways, and other types of the tank that require higher throughputs of water to maintain good water quality. In this approach, the density of stocking or populating the pond is usually two to five times higher than in a semi-intensive pond, where species like tilapia which constitute 7.6 % of freshwater production are cultured in a mix of systems, from extensive to highly intensive. Cage-based aquaculture has progressed in freshwater lakes and rivers in many countries although some countries are now regulating it due to reservations and concerns over environmental impacts. For instance, in Egypt in the year 2005, 10 % of freshwater aquaculture production was from cages in River Nile but by the year 2006, almost 80 % of the cages were removed (from 12495 to a paltry 2702)! It is argued that rapid expansion of the cage-based catfish farming in the Mekong is causing similar concerns but has not led to such a drastic regulatory action of cutting production by massive numbers as was the case in the River Nile cages.

By global representation, Asia leads in the freshwater aquaculture production much as some European and African countries are also contributing significantly as opposed to the Americas where freshwater aquaculture production is quite low. Coastal ponds and lagoons have been exploited in simple ways for fish, mollusc, and crustacean and seaweed production for centuries. However, production has been expanded over the past 30 years were in warmer countries, the shrimps have tended to dominate brackish-water culture due to high value, short production cycles, and accessible technologies. According to FAO (2010), production has increased considerably from the 1970s and by 2007 it was accounting for 58 % of aquaculture production from brackish water (72% by value) whereas, in temperate climates, brackish-water fish species are the leaders and main crops with varying degree of intensification.

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Fish as a cherished source of food

Fish must form part of our regular diet as it is cardinal in the substitution of the protein (essential amino acids) and other nutrients derived from the fish meal is nutritionally straightforward and considerable advances in this field have been made over the past 30 years. For protein supply, the issue is largely one of economics and formulation as well as continual assessment of potential novel sources of protein (such as the biomass-derived from bioethanol production; cereal glutens; microbial proteins; improved oilseed and legume meals, etc.). Even for carnivorous species (high dietary protein levels, sensitivity to the palatability of the feed), up to 75 % of the fish meal in a standard feed can easily be replaced (Bell & Waagbo, 2008). For omnivorous and herbivorous species, fish meal is unnecessary and is only presently used because it is economically viable to do so.

There is a general issue of whether it is ethical, or impacts fish welfare when carnivorous species are fed on 'vegetarian' diets. Also, there is evidence that soya bean induces enteritis in Atlantic salmon and plant proteins in general (which contain wide ranges of nutrient and non-nutrient fractions to which fish are not normally exposed) may have impacts on fish welfare. Substitution of fish oil is considerably more problematic as $n-3$ HUFA (highly unsaturated fatty acids; EPA and DHA) supplied by fish oil, and essential in the diets of truly marine species, are not commercially available from any other source at present. Neither is it desirable to reduce the $n-3$ content of farmed species concerning human health benefits. Considerable progress has therefore been made towards substitution of most or all of the fish oil during the growth phase before introducing a finishing diet, rich in fish oil, that 'washes out' the $n-6$ fatty acids accumulated during growth.

For future supply of HUFA that can be incorporated in aqua feeds, some microorganisms (bacteria and algae particularly) have shown promise and HUFA yields will undoubtedly be increased through conventional selection, improved culture techniques, and/or the use of genetically modified organisms. It may even be possible to combine the production of useful protein biomass and HUFA in this way (Olsen et al. 2008). A further potential source of feed protein and oil is krill (a collective name for a group of approximately 80 species of small, pelagic, shoaling Crustacea). The nutritional issues of product quality (rapid spoilage) and fluorine content have been successfully addressed and viable methodologies for capture and processing developed. CCAMLR3 estimates a total allowable catch that would provide approximately 1 Tera ton of krill meal and 32 000 million tons of krill oil per year from Antarctic waters. However, aquaculture faces strong competition for the krill resource from increasing use of high-grade krill for direct human consumption and production of pharmacological grade krill oils. The potential impact on marine food webs should also be seriously considered.

The disease has proved a major constraint to efficient production in some intensive aquaculture systems. Major improvements in the understanding of the ethology and epidemiology of fish diseases have been made in recent years and aquaculture producers in many countries have dramatically improved their husbandry practices with a greater focus now on fish welfare. Control of many serious infectious diseases has been achieved through new medicines and vaccines, and this is especially true for bacterial diseases. However, new disease problems are emerging, and previously rare diseases becoming much more prevalent, so continued vigilance and solution development are required. Vaccines have been very effective for bacterial fish pathogens where there are resources to develop them, but success against virus disease has been more limited. Nevertheless, fish viral diseases were among the first to be tackled using recombinant DNA technology, specifically for infectious pancreatic necrosis, and subsequently direct DNA vaccination, which appears very promising. As this involves a transfer of genes, there are significant issues of safety and consumer acceptance to be addressed. Another approach showing promise is the use of proteomics and epitope mapping for the identification of vaccine antigens and the subsequent development of peptide vaccines. It is hoped that this approach might be suitable against parasites such as salmon lice. Further methods include the use of virus-like particles which have been reportedly used against grouper nervous necrosis virus or recombinant viral proteins produced in yeast (Renault, 2009).

Aquaculture in Uganda

Aquaculture started in Uganda in 1941 with the introduction of carp into the country by the colonial authorities (MAAIF 2012). Aquaculture production grew from 15,000 to 118,000 tons from 2005 to 2015 due to interventions of government and developmental partners such as FAO (FAO 2004-2020). African catfish (Clarias gariepinus) and Nile tilapia (Oreochromis niloticus) and are the two predominantly cultured fish species in Uganda with production mainly made up of catfish (60%) while Nile tilapia accounts for 40% (FAO 2004-2020). Nile tilapia is widely cultured among the Ugandan fish farmers owing to its prolificacy and tasty appeal (Cai et al. 2017). African Catfish production has been growing and notably common among farmers in the Eastern region as a result of perfection in breeding technology among hatchery operators (Mwanja, 2007). Fish represents approximately 63% of protein consumption in Uganda, with annual per capita consumption of fish estimated at 12.5 Kilograms in 2013, higher than the African average of 10.1 Kilograms (FAO 2004-2020).

Aquaculture production

Uganda is the third-largest aquaculture producer in Africa, after Egypt and Nigeria supplying fish and fishery products in the form of feed, fish seeds, aquaculture inputs, and technical expertise to neighbouring countries mainly Kenya, Congo, and Rwanda (FAO 2004-2020) a study conducted by Safina et al. (2018) reveals that Uganda is the second largest aquaculture producer in Sub-Saharan Africa after Nigeria, with production increasing from about 800 tons in 2006 to 103,737 tons in 2018 (FAO 2004-2020). The aquaculture industry in Uganda directly employs about 24,434 people (FAO 2004-2020). Fish is a high-value commodity and contributes 3% to the national GDP of Uganda.

Popular fish species in Uganda

Nile tilapia (Oreochromis niloticus), until recently used to be the most cultured fish species across Uganda due to its taste, easy reproduction, and growth performance, however, the North African catfish (Clarias gariepinus) production has recently surpassed the Nile tilapia production as common aquaculture species (FAO 2004-2020). The characteristic rapid growth rate of catfish and the ability to feed on the available organic matter available at the household level makes it widely acceptable amongst Ugandan fish farmers (MAAIF 2012). Catfish is predominant in all the water systems in Uganda, particularly water catchments linked with swamps (FAO 2004-2020). The common carp (Cyprinus carpio) is the third most cultured aquaculture species in Uganda; however, insufficient fingerlings production, inadequate extension services, and unstable post-independence government policies hindered the growth of carp aquaculture. Carp culture is still currently abundant in some parts of Uganda, however, at a low scale of production (FAO 2004-2020).

Other aquaculture species that were introduced and being cultured in the country are the giant river prawn (Macrobrachium rosenbergii - De Man 1879) and the red swamp crayfish (Procambarus clarkii). The giant river prawn production in the country is mainly dependent on regular larvae importation while the red swamp crayfish population is well distributed in Lake Bunyonyi and at Kajjansi Aquaculture Research and Development Center (FAO, 2004-2020). Due to limited available data on the current production outputs of each aquaculture species cultured in Uganda, this study presents the aquaculture production output of the dominant aquaculture species documented for 2013.

Freshwater aquaculture production systems in Uganda

Aquaculture productions in Uganda were carried out mainly using pond culture systems, until recently that other forms of fish production systems such as cage culture system are emerging due to the advent of commercial fish farms (FAO 2004-2020).

Pond systems

Fish farmers mostly adopt intensive and semi-intensive pond culture systems in almost all districts of Uganda (Isyagi et al. 2009). The intensive pond production system utilizes smaller and deeper earth ponds which are used mainly to culture sex-reversed Nile tilapia (Mbowa et al. 2016b). Major factors that inform the decisions of fish farmers on the size of ponds are production costs, recommendations by extension personnel, and land size (Isyagi, 2007). Due to the drive for the commercialization of aquaculture production in Uganda, the average pond capacity has increased to 500 m^2 per fish pond (Rutaisire et al. 2017).

Tank systems

Tank systems were first introduced in Uganda in the early 1990s to produce European eels (Anguilla Anguilla) on private farms (Isyagi 2001). Circular and rectangular tanks are currently being used for spawning and seed production by the catfish hatcheries (Rutaisire et al. 2017). Aquaculture tanks of various designs are used generally in modern hatcheries for induced breeding of fish. Most of the hatchery setups typically are made up of breeding tanks, larvae rearing tanks, and holding tanks (Rutaisire et al. 2017). Tank systems are also employed for intensive Nile tilapia and catfish productions using underground freshwater systems (Mbowa et al. 2016b). Tank capacity is dependent on fish management practices, production cost, water quality maintenance, and space utilization (Rutaisire et al. 2017).

Cage systems

The cage culture system in Uganda emerged in 2006 in Lake Victoria and Kyoga as an alternate system to boost aquaculture production and still in its nascent phase (Blow & Leonard, 2007). The continuous decline in capture fisheries from Ugandan lakes and rivers have necessitated the development of cage aquaculture operations promoted by the Ugandan Government as a development priority and supported by development partners such as the Belgian Technical Corporation (BTC), European Union (EU), non-governmental organizations, individual farmers, and youth groups (Kifuko 2015). The most commonly adopted cage system is the low-volume high density (LVHD) cages of 8 m3 with a stocking density of 200–400 fingerlings m−3, depending on the depth and flow rate of water (Rutaisire et al. 2017). The cage system is used predominantly in growing hatchery-produced fry of Nile tilapia (Oreochromis niloticus) using the pelleted aqua feed. Cage culture is adopted currently by the major stakeholders in the aquaculture sector such as research institutions, local governments, private investors, and donor agencies (Mbowa et al. 2016a; Rutaisire et al. 2017). River Nile in Uganda provides favorable temperature and good water quality parameters; therefore, providing suitable opportunities for cage culture development and job creation (Blow and Leonard 2007). The productivity of cage culture is substantially dependent on management practices and ranges from 5 to 35 Kilograms fish m−3. The government policy of restricting the number of cages has been a significant factor affecting operational cages in Uganda (Mbowa et al. 2016a).

Aquaculture policy frameworks in Uganda

The Department of Fisheries Resources (DFR) under the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) is the competent authority in Uganda saddled with the responsibility of inspection, certification, and approval of aquaculture establishments and allied practices (FAO 2004-2020). The overall strategic goal of the fisheries sector is to enhance sustainability in fish and fisheries products production and utilization through well-managed capture fisheries and the promotion of aquaculture (MAAIF, 2021). The DFR is mandated to promote, guide, and support public and private sector partners involved in fisheries and aquaculture activities in sustainable development as well as responsible for setting and enforcing regulations and standards for practices on fisheries and aquaculture (MAAIF, 2021). The DFR also provides services such as technical back-up associated with fisheries and capacity building for Local Governments; information provided for all stakeholder groups; creation of funding strategies for sector development; ensure sustainable resource utilization through good fisheries policy and equitable legal basis for sustainable fisheries and aquaculture management (FAO, 2004-2020).

Out of the many technologies being used on the TAF Assured Mixed Enterprises; specifically, this study was motivated by the composition of aquaculture or fish farming as a path to enhancing smart farming in Uganda. This decision was informed by my inquisition on how a community could utilize my piece of land that borders a low-lying wetland similar to the one being used by TAF for fish farming. It is believed that visiting this project and inquiring into the technology would enable farmers to properly utilize their land through fish farming. In this study, three aspects of aquaculture are covered, namely; (a) the hatchery where eggs are extracted and hatched, (b) water production to sustain the pond and the fish inside, and (c) the pond security as fish is a valuable product that many predators including humans would be tempted to illegally harvest.

The Hatchery

At TAF stands one of the few hatcheries available in northern Uganda. This hatchery specializes in hatching mostly catfish and tilapia species as the farm manager explains. However, catfish take the largest share of this hatchery's activities given the difficult natural fertilization processes of catfish, which is close to impossible in normal-sized ponds like the ones at TAF. This is true because catfish have very erratic mating behaviour which involves the male chasing a female catfish over a very long distance to stimulate the pregnant female. When the female is stimulated, it finally lays eggs in thousands and the male would fertilize these eggs leading to hatching. But because a normal pond is not large or long enough for the chasing to take place, female catfish do not lay their eggs in the ponds due to lack of stimulation. For this reason, therefore, pregnant catfish and good quality males are removed from the pond and taken to the hatchery where the process is scientifically done. The manager notes that female catfish is stimulated by gently massaging a special area on her head after which she is made to stay in a clean drum or chamber of water and given some hours to lay eggs. When these eggs are laid, the male's reproductive semen is extracted and applied onto the laid eggs for fertilization to take place. The eggs are kept in this clean water until they hatch. This process is complete after transferring the hatched fingerlings to several chambers of clean water in this dark structure called the hatchery. A lot of care is taken when the fingerlings are still in the hatcher to ensure that they do not die.

From the hatchery, the young fingerlings are transferred to an open but small pond for the young called "nursery pond." They are then kept in the nursery pond for a few weeks awaiting transfer to bigger ponds for breeding. Anyii says these are the sizes that are sold to new farmers or people who want to restock their ponds while others are sold to fishermen as baits and others can be used to feed other carnivorous species such as catfish which also feeds on the young.

Security of the pond

The major challenge with this project has been the security of the fish in the pond since some local community members have been sneaking into the pond to steal fish as it has been noticed by farm authority. The farm manager says it took him long to know that his fish was being stolen from the pond by some unscrupulous community members until some trustworthy people volunteered the information to him. However, he had received several alerts through hearsay about locals stealing his fish and sharing the story at drinking joints about the saltiness and sweetness of fish from his pond! To curb the theft of the stock, he says he devised two mechanisms which included community sensitization and involving them in digging the dams. In the community sensitization approach, he revealed that he would through the local council leaders invite community members and teach them for free how to do fish farming on small scale and improve on their diet. During these sensitization meetings, locals would also be told about the dangers of trespassing on others' ponds. This, he said dissuaded many would-be thieves from breaching the ponds. Besides these measures, TAF management hired a guard who is resident at the side of the ponds to keep watch over the ponds to guard against incidences of theft of fish.

Another challenge had been other predators such as monitoring lizards, Geckos, and frogs that would eat young fish from both the main ponds and nursery ponds. To address this challenge, the management of TAF ponds procured catapults and trained young boys to shoot the frogs, geckos and monitor lizards from around the ponds. This has drastically reduced the number of these predators around the ponds and proven to be a great source of security to the fish stock. Another element of pond security is the handling of storm water: the manager states that there was a nasty incident at the farm when storm water ran through the pond and swept away 2500 fish from the pond as a result of heavy rain. This challenge was managed by losing some parts of the pond to create a straight waterway for future storm water. He explains that the storm water swept the pond and carried away fish because the pond was constructed on the waterway which was not proper. After the incident, he had to create a straight water channel to avoid any future scenario.

Water production

At the TAF fish pond, water is not a challenge given the fact that the most important aspect of fish farming is constant water supply to keep the dam covered with water, and fish would only live in water. Although much of the farmland is covered by gravel (red stone) down the small valley where the dam is constructed, there is a source of underground water that constantly supplies the pond throughout the year. Even with the above natural advantage, there is a production "Well" constructed at the edge of the pond to supply fresh water to both the hatchery and the pond. Water is pumped from the ground using a generator which powers an electric pump connected to the underground water source. There is also a concrete water tank constructed near the hatcher to store water which is pumped into the hatchery and also to the pond whenever it is needed.

To gather the data used in this write-up, interviews and observations were used as well as reviews of secondary data which were used at the introductory party of this work. Questions were asked to the farm manager and the director who later joined us during the questions and answers session. All questions asked were answered satisfactorily by the two technical officers on the farm; those answers have formed the basis for this report. My pictures while on the farm collecting data is attached to this piece as annexes "A&B". Other than the questions and answers session, discussed above, the writer observed several activities and elements of the farm and later concluded from such observations while some observations were used to ask questions to the technical offices on the farm.

2. THE OUTCOMES

The outcomes cover three aspects contained in the scope, namely; the hatchery, pond security and water production.

The Hatchery

Because of the hatchery, TAF can receive orders from the rest of northern Uganda and supply any number of fingerlings without hesitation. The hatchery receives orders for fingerlings from individual farmers as well as the government through programs such as Operation Wealth Creation (OWC), Northern Uganda Social Action Fund (NUSAF) among others. It should be noted that each fingerling currently costs 250= meaning that the farm earns a lot of money from the hatchery alone which money is injected back into the farm to sustain it. Assuming OWC orders 100,000 fingerlings for farmers, that means a total of Shs.25, 000,000 (twenty-five million shillings) would be generated in revenue to the farm in one go!

Pond Security

The farm has not recorded any major loss of fish in the recent months after strengthening the security system at the pond using multiple approaches such as security guard, snipers who use catapults to kill predatory frogs, traps for geckos, and involvement of local community members in the construction of the ponds have helped in changing their attitude, how they treat the project as their own. The creation of storm water channels has provided additional security to the pond because running storm water cannot wash the pond and its fish away.

Water Production

The production of water at the project site has made it possible for the farm to keep fish throughout the year without experiencing any water shortage. The availability of a clean water source makes it easy for the fish to grow faster since fish get a sufficient amount of oxygen and good life when the water is fresh. This water is the engine of the pond since fish cannot survive without water. Generally, the availability of these technologies has attracted not only farmers but also students from different universities and other learning institutions such as Lira University, Busitema University, Comboni College, Dr. Obote College, St Katherine Girls Secondary School as well as local government officials and non-governmental organizations including CARE-Uganda and World Food Program among others.

3. CONCLUSION

Aquaculture can constitute a good percentage of our household income only if the farming technology could be embraced by majority of farmers in Uganda. Other than boosting household incomes, fish farming could improve nutrition levels in homes and prevent malnourishment among children. Above all, embracing aquaculture has a great potential of enhancing smart farming in Uganda. It is therefore a worthwhile venture for Ugandan farmers given the dwindling numbers of fish in the country's fresh waters.

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