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"One-step at a time": Adopting fish Farming technologies as a smart farming initiative among smallholder farmers in Oyam district, Uganda

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Abstract: **Recent trends indicate that the level of environmental degradation and its impact on climate change is almost irrevocable; the global society has decided that issues of climate change become central to every strategy, policy framework, programmes and intervention. Before this, a number of academics projected that we would reach this level given that human numbers appeared to outgrow all other resources and human needs such as food, housing, public facilities and transportation. As yet, farming, which cannot be stopped due to the need to feed the growing human population, demands a far different trend so that humanity continue surviving. Smart technologies, in every aspect, including farming has thus become the buzzword and nations have no choice but to adopt available technologies. Our paper discusses one of these innovative technologies, fish farming, outside of the traditional freshwaters in lakes, rivers and oceans. We focus on fish farming technologies as a strategy to enhancing smart farming, which is recognised as a frontrunner in offering farmers and humanity a choice to contribute to sustainable development. We conclude that there are many innovative ventures in smart farming but fish farming technologies in terms of construction design of the fish pond, water quality management in the fish pond, feeding of the fish, and marketing of the harvested fish, appear to offer a wider hope. Nonetheless, low-income households will have to keep relying on fish from freshwaters.**

Keywords: **Fish farming, smart farming, Oyam, fish pond, feeding.**

1. INTRODUCTION

China is said to have started fish farming as early as 2000 BC , and the common types of fish that were majorly cultured was brought forward by Fan Lei in 475 B.C. (Villaluz, 1953). Romans constructed fishponds during the first Century A.D and fishpond construction got spread throughout Europe by the religious leaders during the middle ages (Lovell, Shell &Smitherman 1978). Fish farming in the Eastern countries of Europe became prominent during 12th and 13th centuries. In Southeast Asia, fishponds were believed to have developed naturally along with salt making in coastal areas; the salt beds were utilized to grow milkfish during the rainy season. This practice was originated by the Malay natives before A.D 1400 (Schuster, 1952). Early interest in fish culture in the United States was carried over from England before 1800 and was concentrated on propagation and culture of trout salmon. In this there has been application of pond filing technology.

Globally, however evidence indicates that in many areas fishery management is failing (Cichrame, 2000). Though it has been geared toward full employment and social peace, the management of the fishery industry has not achieved this goal. According to FAO reports (2005) the system is not operating in a sustainable and efficient manner. Over the years, however, efforts have been made to develop new technologies, which have been introduced to the industry. This has led to more fish being caught, but this has also resulted in the overexploitation of fisheries (MacLennan, 1995). Among major

producing countries, China, India, Indonesia, Viet Nam, Bangladesh, Egypt, Norway and Chile, have consolidated their share in regional or world production to varying degree over the past two decades. Across the world, the fisheries and aquaculture sector is a major source of employment.

In Africa, the governments of the continent under the aegis of the African Union, identified the great potential of aquaculture and are determined to encourage private sector investment (NEPAD, 2005). A study by Nwachukwu and Onuegbu (2007) shows that the development of aquaculture can only be enhanced by the introduction of modern technologies. While there have been instances of successful introduction of technologies to boost production in Ghana (World fish centre 2005), the major problem has been lack of appropriate technology. In Uganda, fish farming began to develop in 1953 with the objective of reducing incidences of kwashiorkor among children in the central region. Rural households accessed cheap protein through subsistence fish farming, which also increased the availability of fresh fish to communities that lived a distance from the country's natural water bodies. In the 1970s some farmers began earning income from fish farming, and, from the 1990s, following the government privatization and liberalization policy, the fisheries sector contribution to GDP had levelled at 6% percent in 1999, increased to 8% percent in 2001, and has since remained steady at 7% to 8% percent (Isyagi et al., 2009).

A number of farmers got involved in the fish farming in Uganda but most notably among others was Nikimu Fish Farming Project (NFFP) which was an innovative project run by a local fish farmer and Integrated Environment Conservation and Disaster Assessment for Africa (IECDAA) within an aim of mobilizing, organizing and serving small-holder fish farmers in Budaka District locate in Eastern Uganda. NFFP & IECDAA designed a community-based sustainability project that provided the tools and resources needed by youth, women, and other interested local people to fight poverty and improve on the livelihood and health, to feed themselves, their families, and their communities. This Fish farming project was also aimed at improving the nutrition of the local people and the neighbouring communities by providing cheap source of fish protein, and by putting to ultimate self-sustaining use of the available potential places of small scale fish farming in Kamonkoli sub county Budaka District.

On the Local Context, a number of people have started engaging in fish farming to the extent of farming in fish as a business. In the interest of building on my knowledge and skills on smart farming beyond theory, I took a visit to one of the farmers Akello Teddy in Oyam District practicing smart farming in fish farming. Akello Teddy lives in Barcal Village, Wirao Parish, Aber Sub-county in Oyam District. In fish farming, there are a number of technologies being used in the practice that includes among others; Improved techniques in pond construction and maintenance, Introduction of modern fish hatchery equipment, Introduction of improved fish seeds/species, Aeration for transporting fingerlings to reduce stress and mortality, Modern harvesting methods, Improved water quality management, Fortification of fish feed, Prevention and control of fish diseases as well as Integrated fish farming and record keeping. Of the above, I have interested myself on the improved water quality management.

The introduction of technologies has improved on fish farming processes to the extent that, fish farm management can be automated to be easily and remotely monitored from other location saving time and money making fish farming more efficient and even eco-friendly. Advancements in technology generally have supported the modernization of fish farming. Some technological inventions are tailor-made for aquaculture or fish farming operations. For example, design of semi-submersible cages, automatic time-controlled feeders and water recirculating and remediation systems require specific technology applications based on sound scientific knowledge. The visible benefits from technology have provided a supporting basis for advancing the fish farming system to the next higher level which is the application of computer controls and artificial intelligence (AI) for a greater degree of automation, effective management and decision-making.

Improved water quality management for fish farming

A great deal of knowledge has been generated in fish farming and this has contributed to industrialization of this sector, Mustafa et al (2016). This industrialization is associated with introduction of technology since a large number of parameters have to be controlled in modern-day fish farming systems.

To achieve a high production of fish in the pond, regular maintenance and monitoring is vital. Daily management includes: checking the water quality (oxygen, pH, colour, transparency, temperature, etc.) checking the pond for possible water leaks, cleaning the screen of the water inlet and outlet, observing the fish while they feed. For purposes of this study, the centre of focus has been on the improved water quality management technology in fish farming being used by

Mrs. Akello Teddy (farmer). In the process of my interaction with Akello Teddy, the following key issues surrounding the improvement of water quality management came out as important elements of fish health management that should be considered. This includes among others; the source of water, Water Supplies in to the pond, maintenance of the cleanness and the general hygiene of water in the pond, empting and refilling of the pond as well as treatment on regular basis.

In fish farming, proper water quality maintenance is the primary preventive measures against fish diseases as fish are very sensitive to water condition like toxin and temperature. It is imperative that a fish farmer maintains the hygiene of the water in the pond as much as possible in order to provide environment conducive for good fish health. The cleanness and hygienic condition of the water in the pond should be regularly checked through physical detection and or water testing. The water tests allow you to take a look at the water composition, because water can be clear and still contain toxins. The quickest and easiest way to carry out water tests is with test strips (JBL Proaquatest 7in1 and JBL Proscan). In just one minute you have the result for the most important 7 values, this is even readable by smartphone. If you want to know exactly, take the JBL drop tests. With the help of these tests, which are also used on scientific expeditions all over the world, you can analyse your water condition extremely accurately and reliably. However, with all the technologies available for the fish farming management, the local fish farmers has not yet appreciated them. This has an adverse effect on the quality and quantity of fish production. Akello Teddy, a farmer in fish is able to maintain the hygiene of her fish pond by ensuring regular empting and refilling of the fish pond. In her practice, she empty and refill the pond on monthly basis as this she said to have maintained the hygienic condition of her fish pond and the general health of fish.

It is imperative to learn of how the existing fish farmers of similar geographical location are practicing fish farming as well as getting in to the knowledge of the application of technologies in fish farming. For proper management of fish farming, a number of technologies has to be applied that includes among others; Improved techniques in pond construction and maintenance, Introduction of modern fish hatchery equipment, Introduction of improved fish seeds/species, Aeration for transporting fingerlings to reduce stress and mortality, Modern harvesting methods, Improved water quality management, Fortification of fish feed, Prevention and control of fish diseases as well as Integrated fish farming and record keeping. Of the above technologies, fish farmers especially on small scale still faces the challenge of maintaining water in their different fish pond as well as the hygienic condition especially during dry season. This greatly affects the health of the fish as well as the level of production, profitability and sustainability in fish farming as a means of income generation to farmers. Specifically, the study covers four issues; Construction design of the fish pond, Water quality management in the fish pond, feeding of the fish, and Marketing of the harvested fish.

In getting the relevant information necessary for this write-up, I was able to review some few literatures in relation to fish farming (Literature review), having a face to face engagement with the farmer (interview) as well as observing the technology and events (observation). This was initiated through contacting the smart farmer in advance to seek acceptance and agree on a mutually convenient date, time for the interview. This was after presenting an **e**xplanation on the purpose of the interview as well as the purpose for which the information got from her (farmer) will serve. In this case, we had several predetermined questions/areas of interest to ask and get feedbacks. The questions were more of open-ended in which the smart farmer had the freedom to provide a response she was comfortable with. In ensuring the information collected was rich in content, we made sure there were follow-up questions for areas where the farmer had provided ambiguous information. Along the way, I was also able to use the observation technique and noted some vital aspects from the fish farming site and had them noted. I later sorted the information I got from the farmer and noted it for purposes of formulating this paper as well as building on my knowledge for my personal practice.

2. THE OUTCOMES

The construction design of the fish pond

Akello Teddy has constructed an artificial fish pond of a rectangular shape of 15 meters by 25 meters in width and length and 1meter in depth with one inlet water gate at one end and one outlet gate in the other end. The floor of the fish pond is cemented in a roughcast with entrance/exit made in steps to allow for easy getting in and out whenever the pond is to be accessed. The pond is filled with water up to about 50 centimetres above ground or pond floor level. Akello Teddy (farmer) has installed a water pump that pumps water to the fish pond. This pump uses an electric power energy to pump water in to the fish pond until it reaches a level required. In the fish pond building, the following are the suggested steps as below: Prepare the site, Build a clay core (in the case of contour ponds), dig the pond and build the dikes, build the inlet and outlet, protect the pond dikes, fertilise the pond, fence the pond, fill the pond with water and stock the fish.

Management of the quality of water

Good water quality is characterised by adequate oxygen, proper temperature, transparency, limited levels of metabolites and other environmental factors affecting fish culture. Dissolved Oxygen is essential for the survival of aquatic life and is incorporated into surface waters by direct absorption from the atmosphere. Dissolved Oxygen refers to the level of free, non-compound oxygen present in water or other liquids. It is then consumed by organisms and decaying organic matter. An excess of decaying organic matter leads to a shortage of oxygen, which can prove fatal for fish. Dissolved Oxygen is necessary to many forms of aquatic wildlife, fish need dissolved Oxygen for respiration. If dissolved Oxygen concentrations drop below a certain level, fish mortality rates will rise. Areas with little or no dissolved oxygen are known as dead zones as aquatic organisms cannot survive there. These zones are often located near areas that are heavily populated with people. Water quality management can also be done through measuring of water temperature.

Temperature extremes can be harmful to fish, and also have an effect on other parameters, e.g. pH and dissolved oxygen. The most common physical assessment of water is temperature. Temperature has a huge impact on both the chemical and biological characteristics of surface water. The temperature in water can make the fish extremely sensitive to disease. Warm water is less capable of holding dissolved oxygen which can be fatal to fish life. It can leave fish in a weakened physical state making them more susceptible to diseases and pollutants. For this reason temperature should be monitored at the same spot in the water at which dissolved oxygen is monitored. To Mrs. Akello Teddy, she usually empty her fish pond regularly after every one month by means of pumping the water from the ground.

Feeding of the fish

Fish under intensive culture rely entirely upon the nutritive quality of artificial feeds. Diet selection, feeding frequency, and quantities fed are controlled by the fish culturist. Nutritional problems, arising from dietary imbalances, continue to cause problems in cultured fish even though great advances have been made in the knowledge of the nutrient needs of fish. For pond owners or fish farmers, it is important to know how to care for them and help them grow, but what do fish eat in a pond, and do you need to actively feed them? It is indeed true that under natural circumstance, fish can feed on algae, weeds, insects, leeches, and worms as their food. However, fish also need supplemental nourishment for better quality and high productivity.

To maintain a natural balance in your pond, we recommend stocking a good ratio of prey to predator fish and adding minnows from time to time. If you're trying to help them grow quickly so you can use your pond for fishing, supplemental nutrition is key. The kind of food provided to the fish should be packed with high amounts of protein and vitamins to encourage growth and provide balanced nutrition to increase resistance to common diseases. Also remember to look for high-quality foods that contain better ingredients for your fish. Lower-quality foods will be harder to digest and pass through fish, adding unnecessary nutrients to the water, which can cause water clarity issues. Look for fish food with at least 40% protein for fast growth and vitamins to keep them healthy.

On the question of how much to feed the fish, I have realized that this depends on the size of the pond, number of fish, and whether or not you use a pond aerator are all factors that affect how much a farmer need to feed his/her fish. Aeration in the pond will allow your fish to be more active, requiring you to feed them more. According to Akello Teddy, a fish farmer whom I visited, he feeds his fish two (2) times a day. On when to feed the fish, how and of what quantity, Akello Teddy stated that, this depends greatly on the water temperature, the number of fish in the pond and the size of the pond. She said when the water temperatures is below 50°F (10°C)in the pond, fish will eat less compared to when the water is warm and above 50°F (10°C). This is because when water is cold, fish tend to go in to hibernation until temperature increases. Akello Teddy with a fish pond of 15 meters by 25 meters in width and length respectively and 2500 fish, she gives 2.5kgs of feed per every single feeding two times a day. She added, this, she expect the fish to eat in about ten minutes depending on the water temperature.

Marketing of the fish

Marketing of fish could be regarded as the performance of all business activities involved in the flow of fish from the point of production (fisherman or fish farmer) to the final consumer (Olukosi et al., 2007:76). According to Akello (a fish farmer visited), there are a number of marketing channels ranging from primary and Secondary market. She said primarily, she sells her fish at his village and the surrounding places (village/ home market), some local market places, district headquarters especially to the staffs of Local Government and NGOs. She said this markets are more

economically friendly as it does not require an exorbitant cost of transportation of the fish (affordable transport) whenever it is necessary. Akello said she has already started widening her market base to outside market like retailers and whole sellers who buys in large quantity for further sales as a business.

As a marketing strategy, Akello Teddy has developed a good marketing plan that contains a marketing strategy that guides the business into profitability. She said after a period of two years, she realised there are so many upcoming fish farmers within her area and that her market was under threat and would demise, and to gain a fair share of the market size, she had to start on the right marketing strategies to make her retain the market. Nevertheless, there is a need for Uganda as a country to develop marketing strategies for aquaculture (fish) development as the industry is continuously faced with a number of challenges ranging from lack of reliable information and simple communication from and between markets and fish farmers is lacking, the question of value-addition and market strategies when targeting premium markets have not been fully addressed as well as cost of accessing lucrative markets (i.e. transport and roads infrastructure) that can be prohibitive for rural fish farmers, especially when dealing with live, farmed fish.

Proposed stages in fish farming and the average standard

Activity/Item	Recommendations
The Pond	▪ Well compacted pond levees with a slope of at least 2:1 for commercial grow-out ponds. ▪ Average water depth in pond of 1 – 1.2 meters (0.8 – 1.0 m at shallow end to 1.0 – 1.5 m at the deep end). ▪ Inlet pipe at least 20 cm above the pond water level and screened with a properly fitted filter sock. ▪ Outlet pipe fitted with an anti-seep collar and screened correctly with cone mesh. ▪ Freeboard of about 15-30 cm. Ponds less than 400 m2 can have freeboards of 15 cm. ▪ Having a harvest basin within the pond is optional but can be quite useful at final harvest. ▪ The pond must be able to drain completely for complete harvesting and drying.
Pond Preparation	▪ Remove silt from pond. Soil removed from the bottom should be put back where it came from, i.e., used to repair pond levees. Excess should NOT be put at the top of the dam but rather away from the ponds. ▪ Ensure pond is not leaking. ▪ Correctly screen the inlet and outlet. ▪ Lime the bottom of the ponds, if needed, based upon alkalinity and hardness levels (especially of new ponds). ▪ Fill pond. Ponds should be stocked within a week of filling with water
Stocking	▪ Stock only fish in good condition. Stock fish with no obvious signs of injury, excessive stress or disease that have been packaged and transported in bags with adequate amounts of oxygen or in well aerated tanks. ▪ Stock based upon targeted harvest size and the pond's carrying capacity. ▪ The minimum stocking size for grow-out ponds should be fish of not less than 10 cm in length or 5 grams average weight. An initial nursery phase of one (1) month, however, is recommended when 4 fish come in straight from the hatchery before the fish are stocked into the grow-out pond. Having an initial nursery phase helps one have better control of the inventory and improves survival rates. ▪ The targeted harvest size will be intended market size if you are not following a split production plan.
Pond Water Management	▪ Water in the pond should be regularly replaced to avoid fish being in a contaminated water which is very bad for their health and growth. ▪ Water temperature in the pond should be regularly checked. ▪ The pond should be protected from other external strangers to avoid poisoning of the water.

Feeding	▪ Train fish to feed in the same area of the pond. ▪ Training fish to feed enables a farmer to see his/her fish daily throughout the production cycle. This is of great value when it comes to assessing the number and size of fish in the pond in between sampling times as well as monitoring fish health. ▪ Feed fish based upon their feeding response using the catfish feed chart as a guide to estimate daily feeding needs. Pay attention to the number of meals fish of a particular size should be given per day. ▪ Keep recommended feeding records including both the amounts given and response at each feed. ▪ Use the records continuously to evaluate feeding performance in tandem with the pond records to adjust the feeding regime.
Sampling	▪ Sample monthly by seining a small portion of the pond to monitor for growth. ▪ Calculate new feed amounts based upon the actual average fish weights obtained at sampling. This will help make adjustments from the predicted fish weights on the feeding chart and allow re-adjustment to the fish's feeding requirements. ▪ Record data in the pond records correctly at each sampling. Doing so will help with inventory control as well as monitor progression to the pond's critical standing crop. Zero fish growth is an indicator of the pond having reached its carrying capacity.
Record Keeping	▪ Pond and feed records must be kept correctly as recommended. ▪ Records of all inputs used for fish production (e.g. pond repairs, labour, fertilisers, etc.) as well as of all sales should be kept so as to calculate profit.
Harvesting	▪ In order to obtain the best returns, the pond should be harvested before it reaches its carrying capacity, at critical standing crop. ▪ The best way to harvest the pond completely is: ✓ Check your records and know your estimated standing crop. ✓ Seine the pond one or two times to remove the bulk of the fish when the pond is still full. ✓ Reduce the water level about halfway then seine once or twice to remove the rest of the fish. ✓ Drain the pond completely and pick up the rest of the fish. If the pond has a harvest basin that is correctly constructed, the remaining fish will collect in the harvest basin.

Source: *Isyagi, N. A., Veverica, K. L., Asiimwe, R., & Daniels, W. H. (2009). Manual for the commercial pond production of the African catfish in Uganda. Kampala.*

3. RECOMMENDATIONS

From the study, it is recommended that;

a) The aspect of value addition - Framers engaged in fish farming should extent their focus to value addition as a way of maximizing on their profit as well as widening their market for their fish production. In the quest for that, they can either operate individually or form a group of fish farmers association within a particular area, seek support from government for technologies and marketing among other support the government can offer.

b) Record keeping of the transactions of the farmer - Fish farmers should undergo a rigorous training on; pond management, marketing and record keeping.

4. CONCLUSION

Fish farming has become an important resource both globally and locally to meet the food and nutrition security needs of a rapidly expanding human population. Fish farming conditions should be improved in a way that controls the spread of diseases, which negatively impacts on the development of the sector. Environmental problems, such as poor water quality,

and other stressors often contribute to the outbreak of infectious and non-infectious fish diseases. The growth of fish, the length of time spent, effort and amount of harvest a fish farmer have every season is based on the water environment parameters that a pond has. Controlling these parameters to make the pond environment a desirable one for fish to grow normally is a great help for the fish farmers. With the use of technology, better fish farming results can be achieved. Monitoring and controlling the water environment parameters are great factors to maximize fish production in the fish farm.

Successful disease control involves a careful program of fish health management that removes infected stocks, prevents re-infection, reduces stress, and maintains optimal production conditions. Unless an effective fish health management program is promptly initiated, disease will reoccur whenever stresses that increase susceptibility reappear. If fish are provided with a good environment and adequate nutrition, the risk of infection is greatly reduced. Fish farmers should maximize the use of technology for them to increase their production. Then, for the fish to grow normally, the pond environment parameter must be desirable for them to live. With fish farming technologies such as Aqua-Tech, managing their fishponds and controlling environment parameters are easier and safe. The smarter the way of fish farming, the more productive it gets.

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