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TOWARDS REUSE OF AQUACULTURE EFFLUENTS FOR SUSTAINABLE CROP PRODUCTION IN THE DRYLANDS: A PRELIMINARY INVESTIGATION

[1]Abubakar, L. A., *[1,2]Bello, M. M., [1]Shanono, N. J.

[1]Department of Agricultural and Environmental Engineering, Bayero University, Kano, P.M.B. 3011, Kano State, Nigeria
[2]Centre for Dryland Agriculture, Bayero University, Kano, P.M.B. 3011, Kano State, Nigeria.

*Corresponding authors' email: mmbello.cda@buk.edu.ng

ABSTRACT
The aquaculture industry generates substantial amounts of effluents that may cause environmental pollution if not properly handled. However, since it may contain nutrients, aquaculture effluents could offer a sustainable source of irrigation water in the drylands, which are characterized by water scarcity. This paper provides preliminary findings on aquaculture effluent generation and management in Kano State which is located in Nigerian drylands. Surveys were conducted to obtain information related to the production size, sources of water, and effluent handling. 87% of the surveyed farms are small-scale and medium-scale enterprises, with capacities below 5000 fish. Catfish and Tilapia are the commonly produced fish, with 67% of the farms producing the former. Groundwater is the common source of water utilized by farms, accounting for about 72% of the total. Our findings indicate that there are no established criteria for changing the pond water, with the farms considering either the color of the water or its duration in the pond. Most of the farms change the water every 1 to 2 weeks while considering the change in color as the major criterion. The majority of the farms discharge the effluents directly without any treatment. Although some of the farms claimed to be treating their effluents, we could not establish the presence of treatment technologies on the farms. Unfortunately, most of the farmers are unaware of the environmental implications of discharging the effluents without treatment. Further studies are needed to characterize these effluents and to evaluate their suitability as irrigation water.

Keywords: Sustainability, Water management, Peri-urban agriculture, Circular economy, Irrigation

INTRODUCTION
Aquaculture is among the fast-growing sectors in agriculture, providing a source of livelihood to many people and contributing towards bridging the gap in the global protein demand-supply chain. In 2020, the World production of aquaculture stood at a total of 122.6 million tonnes, with an estimated total farm gate value of $ 281.5 billion (FAO, 2022). As the global human population expands, it is projected that the demand for aquaculture will reach 62% of the total World production by 2030 (Ahmad et al., 2021). The development of aquaculture will therefore continue to be on the increase as one of the viable sources of adequate fish supply to meet global dietary protein needs (FAO, 2020; Naylor et al., 2000). Due to the benefits of the aquaculture industry, many countries have strategically expanded the sector. In Nigeria, aquaculture is rapidly growing as a key agricultural sector that provides employment opportunities and contributes to food security and economic development (Adeleke et al., 2020). Currently, Nigeria is the second-largest aquaculture producer in Africa and the largest in Sub-Saharan Africa (Diyzee et al., 2022).

Although the aquaculture industry brings positive economic development, it also serves as a potential source of environmental pollution. Aquaculture production generates a lot of wastewater containing diverse organic and inorganic pollutants that may cause environmental pollution. Due to its polluting potential, the discharge of untreated aquaculture effluents has gained serious attention and threatens the sustainability of the aquaculture industry (Dauda et al., 2019). The effluents from the aquaculture industry contain nitrogen and phosphorus, which may lead to eutrophication in the receiving water sources (Coldebella et al., 2018). Proper management and treatment of aquaculture effluent are therefore necessary to avoid environmental pollution and ensure the sustainability of the industry.

In Nigeria, aquaculture farms are mostly located around the urban and peri-urban areas where their effluents pose significant challenges. The direct discharge of aquaculture effluents, which is commonly practiced, has been associated with environmental pollution. For example, Omofunmi et al. (2016) evaluated the impacts of effluents from fish farms in Southwestern Nigeria and reported that the effluents are discharged directly into water bodies causing significant pollution. In addition, the impact of the effluents on the environment depends on the discharge methods, effluent volume at harvest, and the concentrations of the pollutants in the effluents. Organic residues tend to accumulate while nutrients such as phosphorous and nitrogen may eutrophicate the water bodies (Avnimelech and Ritvo, 2003).

Various efforts have been made to develop treatment technologies for aquaculture effluents (Igwegbe et al., 2021, 2019; Martins et al., 2021; Omitoyin et al., 2017). However, these technologies are mostly based on end-of-pipe approaches, where the focus is on treatment and discharge. Since aquaculture effluents may contain sufficient nutrients (nitrogen and phosphorous) that may support crops, a more sustainable solution will be to utilize it as irrigation water for crop production, particularly in water-scarce areas (Alupo et al., 2016; Van Tung et al., 2021). Due to the constraints in irrigation water in many parts of the world, particularly the arid and semi-arid regions, there is emerging interest in utilizing wastewater for agriculture (Agbogidi et al., 2023; Singh et al., 2012). Hence, wastewater from diverse sources, including aquaculture effluents, could be used as irrigation water, particularly in urban and peri-urban agriculture (Yusuf, 2007).

Many studies have been reported on aquaculture effluents in Nigeria, including their potential use in agriculture. Famoofo and Adeniyi (2020) studied the impact of aquaculture effluents discharged from a medium-scale fish farm on the water quality of Odo-Owa stream in Ogun State, Nigeria. Akinsulire et al. (2018) evaluated the impact of fish farm effluent on water and sediment quality of the receiving Coastal Ecosystem in Lagos. Omofunmi et al. (2017) surveyed the management of catfish effluents in Lagos State, Nigeria. Agbeja and Adetunji (2019) reported the management practices of aquaculture in Osun state, with a focus on the implications for sustainable development. Igwegbe et al. (2022) reported the treatment of the aquaculture effluents coagulation-adsorption process using *Picralima nitida* extract as a green coagulant. However, these studies are limited to the southern parts of the country and there is a dearth of information on the status of aquaculture effluents in Northern Nigeria.

The generation and management practices of aquaculture effluents may differ across regions due to the socio-economic and ecological diversity. To fill the knowledge gap, this paper presents a preliminary work towards a comprehensive study on aquaculture effluents management in Kano State, with a specific focus on its application as irrigation water to support peri-urban vegetable production. It provides the results of a survey conducted across some aquaculture farms in the State, with a focus on the production size, type of fish, sources of water, and effluent management practices. More studies are currently ongoing to comprehensively characterize the aquaculture effluents with the view of promoting their sustainable utilization to support crop production in the semi-arid region. This study aimed to conduct a comprehensive survey on the generation and management of aquaculture effluents in Kano State, with a view of their sustainable utilization for crop production in the State.

MATERIALS AND METHODS

Description of the Study Area

Kano State is located in the Northwestern part of Nigeria and lies on Latitude 12.0022° N and Longitude 8.5920° E. Its Capital, Kano City, is the second largest industrial and commercial centre in Nigeria and lies between latitude 110 05’ N to 12007’ N and longitude 8023’ E to 8047’ E. This study was conducted in the six metropolitan local governments of Gwale, Kano Municipal, Tarauni, Nasarawa, Dala, Fagge, and the two pseudo-metropolitan LGs of Ungogo and Kumbotso. A detailed description of Kano Metropolis can be found elsewhere (Isa et al., 2016). Preliminary information obtained shows that the clusters of fish farms are mostly located within these LGs and are therefore chosen for the study.

Data Collection and Analysis

A well-structured questionnaire was designed and administered to the selected aquaculture farms. At the pilot stage, 8 farms were selected and the questionnaires were administered to them. For the survey proper, a total of 40 fish farms were randomly selected and the questionnaires were administered to them. The questionnaires sought information related to the scale/size of production, type of fish produced in the farms, sources of water used, water management, and effluent handling and discharge. The data collected was analyzed using descriptive statistics. All analyses were conducted using OriginPro 2017.

RESULTS AND DISCUSSION

Farm size and type of fish

The results of the survey of the aquaculture farms across the targeted local governments are presented in this section. Out of the 48 questionnaires administered, only 39 were filled and submitted back. In terms of production size, we categorized these farms into small-scale (<1000 fishes), medium-scale (1000 – 5000), and large-scale farms (>5000). The results of the responses from the questionnaires (Fig. 1) show that medium-scale fish farms (1000-5000) constitute the highest proportions of fish farms across the study area with 56%, followed by small-scale fish farms with 36%. On the other hand, only about 8% are considered as large-scale having more than 5000 fishes. This trend corresponds to the typical characteristics of the Nigerian agricultural ecosystem which is dominated by small-scale and medium-scale enterprises. Catfish and Tilapia are major types of fish produced by the farmers in the area (Fig 2). Catfish is the common fish grown by the farmers in the study area which makes up to 66% of the type fish grown in the study area. Tilapia is the second most common type of fish grown by the fish farmers in the study area with about 26% of the proportion. Other types of fish grow in the study area include salmon, shrimp etc which make up about 8% of the total fish grow in the study area. These findings correspond to previous studies in other parts of the country where catfish was reported to be the dominant type of fish produced (Adeleke et al., 2020). The dominance of catfish might not be unconnected with its adaptive features which make it survive in a wide range of temperatures including the high temperature of Kano. Other authors have attributed this to the hardiness of catfish, wide acceptability, and high market value (Emmanuel et al., 2014).

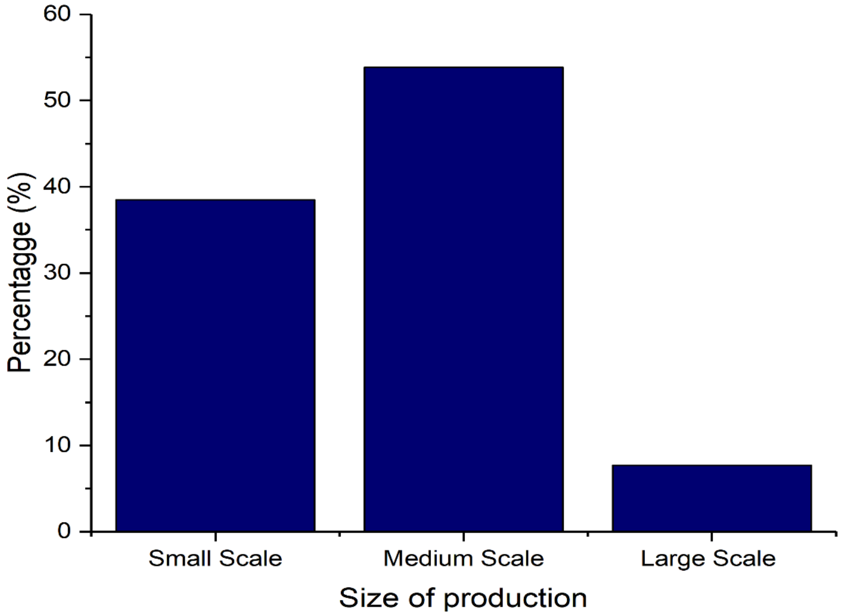

Figure 1: Size of production of the aquaculture farms (small-scale: <1000 fishes, medium-scale:1000 – 5000 and large-scale: >5000).

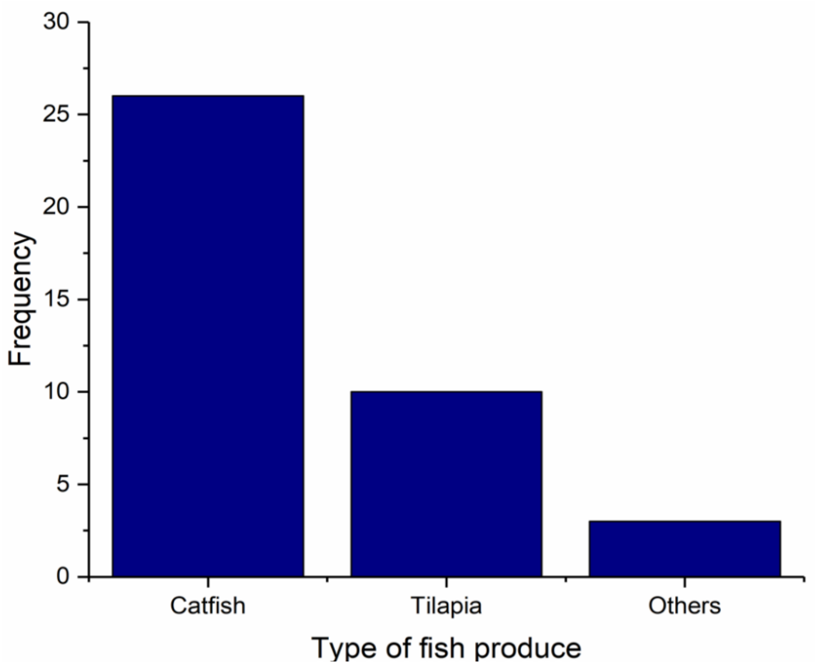

Figure 2: Types of fish produced at the farms

Sources of water and aquaculture effluents management
The sources of water, duration of water in the pond before discharge, criteria for changing the water, method of discharge of effluent, and utilization of effluent were investigated to know the aquaculture effluent management by the fish farmers in the study area.

Sources of water
Fig 3 shows the water sources used by the fish farmers in the study area. The results show that the majority of the fish farmers, constituting about 72% of the fish farming population in the study area, used borehole/well water as a source of water for their aquaculture while 13% and 15% of the farmers used stream/river and tap water respectively as the sources of water for their fish farming. These results correspond with the current trend of water resources utilization in Kano State. Most of the industrial activities in the State, including peri-urban agriculture, utilize boreholes as a source of water. In Aquaculture, this is also the case since about 72% of the farms utilize the borehole/well as a source of water. This highlights the reliability of boreholes as the source of water for aquaculture production in Kano State. These findings agree with the results reported by Omofunmi et al. (2017) where 80% of the surveyed fish farms utilized groundwater as the main source for their production. It can be seen that some of the farms get their water from streams and rivers. We speculate that these farms are located close to these sources, and it is therefore easier for them to just tap water from these sources. However, the quality and quantity of water from these sources need to be assessed to establish their suitability.

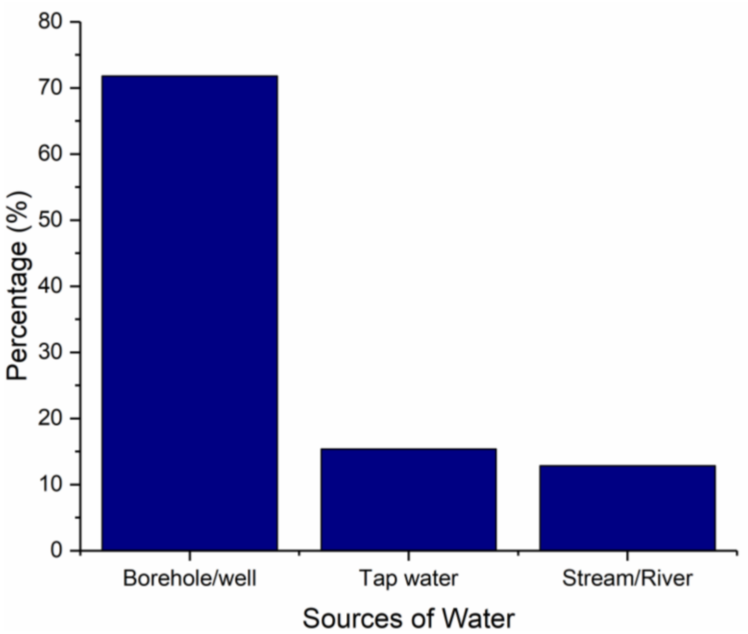

Figure 3: Sources of water used by the aquaculture farms

Duration of water in pond and criteria for discharge

The duration of water in the pond is an important consideration since it can have implications on the fish's health and subsequent effluent management. Therefore, we sought information regarding the duration of water in the pond before it is changed. Fig. 4 depicts the average range of time taken before changing the water in the fish pond. Our findings indicated that most of the farms, about 72%, do change the water in their fish pond within 1 to 2 weeks while 25% of the farms change the water within 2-4 weeks. On the other hand, 3% of these farms change the water after more than 4 weeks. The delay in the change of water in the fish ponds for more than 4 weeks might be due to the inadequate water in those areas.

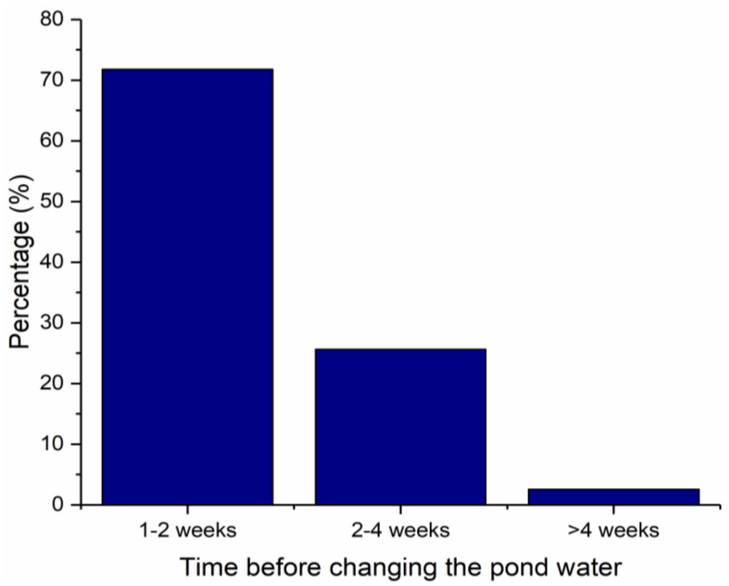

Figure 4: Duration of water in the fish pond water before discharging

Information related to the criteria for deciding when to change the pond water was also sought from the farmers. Based on preliminary findings, the criteria for discharging aquaculture effluents by the fish farmers were divided into three, including discharging based on the colour of water, discharging based on the duration of water in the ponds, and other criteria that are peculiar to the farmers. Fig. 5 shows the percentage distribution of the farms based on the criteria used to discharge their aquaculture effluents. About 46% of the farms consider the color of the water as the key factor in changing the water. On the other hand, 44% of the farms do consider the duration of the water in the pond, irrespective of the color change. The discharge based on other criteria which include the availability and the cost of getting the water to replace the discharged one constitutes about 10%. This indicates that there is no established standard for changing the water, and the decisions for changing the water are largely subjective. However, since the concentration of organic pollutants may affect the dissolved oxygen in the pond, which will have a detrimental effect on the fish, objective criteria must be adopted for determining when to change the pond water.

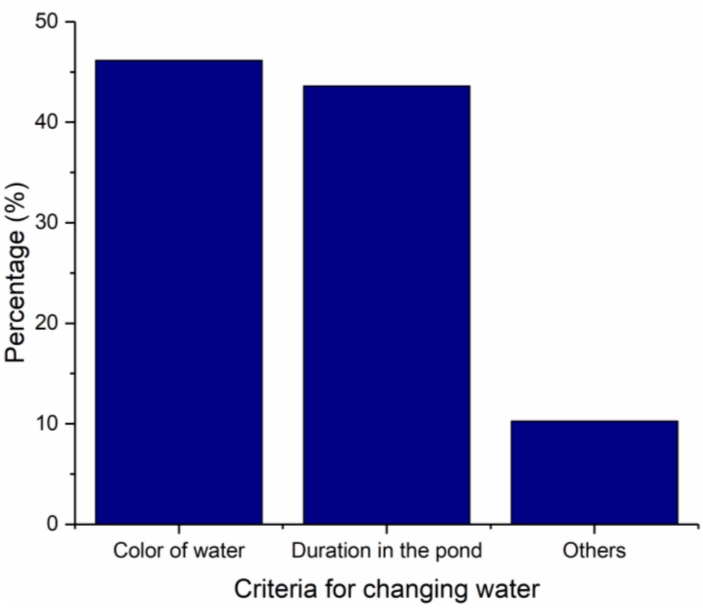

Figure 5: Criteria for changing pond water

Effluent handling and discharge
The method of discharging aquaculture effluents by the farmers was divided into two and they include treatment and discharge, and direct discharge to drainage. Fig. 6 shows the methods of discharging aquaculture effluents by the farmers in the study area. The majority of the fish farmers (59%) discharge their aquaculture effluents directly to drainage while 41% of the fish farmers claimed to be treating the effluents before discharging to drainage. The direct discharge of aquaculture effluents to drainage which is common in the study area is in line with FAO, (2009) which revealed direct discharge of aquaculture effluents is common among fish farmers in Africa. Omofunmi et al. (2017) reported that 95% of the catfish farms in Lagos State discharge their effluents without any form of treatment. This practice may be reinforced by the weak implementation of regulations guiding the discharge of effluents into the environment. Whilst some of the farms claimed to be treating the effluents before discharge, we could not establish the presence of treatment technologies in these farms. However, some farmers considered the mechanical removal of algae from the ponds or effluents as a treatment. It is therefore imperative to state that aquaculture effluents are largely discharged directly without any treatment, despite their potential impact on the environment. The direct discharge of nutrient-rich effluents into the environment is perhaps the major drawback of the aquaculture industry (Sikder et al., 2016).

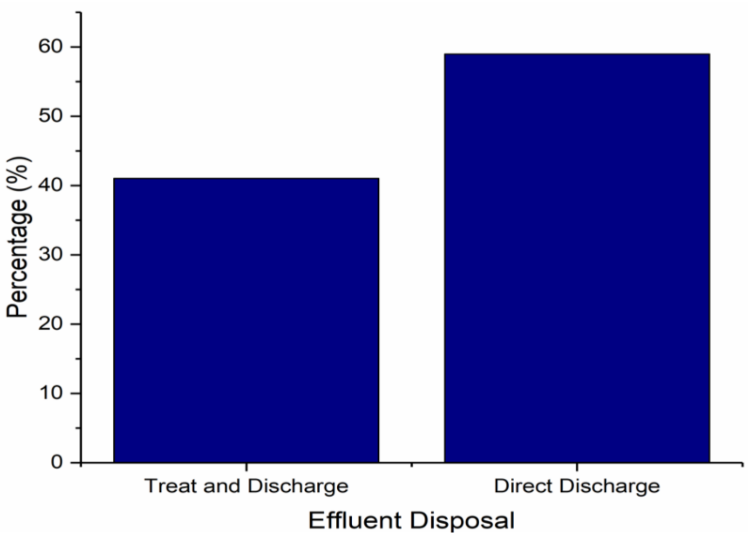

Figure 6: Effluents handling

Considering that most of the farms discharge the effluents directly, we sought information about the farmers' knowledge of the effects of the effluents on the environment. Fig. 7 depicts the percentage distribution of the farmers' knowledge about the effects of aquaculture effluents on the environment. A large proportion of fish farmers, constituting about 72% of the surveyed farms, have no idea about the effects of the effluents on the environment. However, about 28% of the farmers responded to having some knowledge of the effects of aquaculture effluents on the environment. These findings explain why most of the farms discharge the effluents directly without any treatment. Previous studies have reported similar observations about the awareness of the potential danger of discharging untreated effluents by the farms (Omofunmi et al., 2017). The farmers' lack of common knowledge is a source of concern since aquaculture effluents may contain various pollutants, including high concentrations of nitrogen and phosphorous, that could cause eutrophication in the receiving water bodies. Whilst there are treatment technologies that could be deployed to treat aquaculture effluents for their subsequent discharge, a more sustainable management option would be to recycle the generated effluents. The government and other stakeholders in the aquaculture industries need to enlighten, educate, and create awareness on the negative impact of discharging aquaculture effluents directly to the environment.

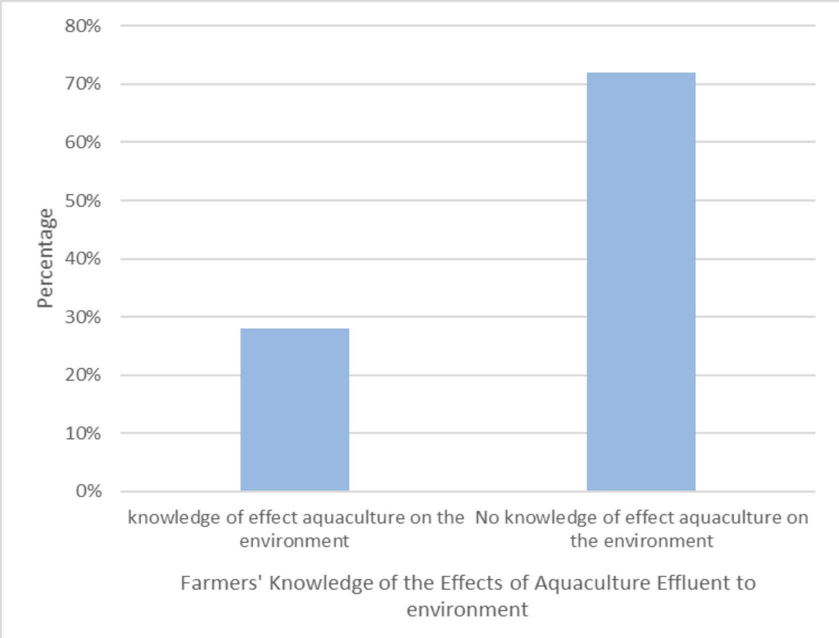

Figure 7: Farmers' knowledge of the effects of aquaculture effluents on the environment

CONCLUSION

Aquaculture production generates huge quantities of effluents that can cause environmental pollution if not properly handled. However, if properly managed, aquaculture effluents may be utilized to support crop production, particularly in water-scarce areas. This paper reports the results of a preliminary study on aquaculture effluent generation and handling in Kano State, with a focus on its utilization for vegetable production in peri-urban areas. Most of the farms surveyed are small-scale to medium-scale enterprises, with production capacities below 5000 fish. Catfish and Tilapia are the commonly produced fish in these fish farms. With regards to effluent handling, our findings indicate that there are no established criteria for changing the pond water, with the farms considering either the color of the water or just the time it has stayed in the pond. Therefore, more objective criteria, such as the level of dissolved oxygen in the pond, need to be adopted. Further studies are therefore needed for a comprehensive characterization of the effluents, including their temporal variation in the pond.

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