THE EFFECT OF WATER QUALITY AND NUTRIENT ACCUMULATION ON RICE GROWTH IN INTEGRATED AQUACULTURE-AGRICULTURE

ABRAHAM, O. V. [1*], AKINWOLE, A. O. [2], ADENIYI, A. O[2], ABDULLAHI, U. U [3] and AKPOBOME, S. O. [4]

[1*]Department of Fisheries and Aquaculture, Nigeria Maritime University, Nigeria
[2] Department of Aquaculture and Fisheries management, University of Ibadan, Nigeria
[3]Departmennt of Agricultural Technology, Niger State College of Agriculture, Nigeria
[4]Department of Botany, University of Ibadan, Nigeria
Corresponding Author:* Email: babyvichuks@gmail.com. +2348039114592

ABSTRACT:
This experiment was conducted to evaluate the effect of Water Quality on rice growth performance in an integrated aquaculture-agriculture surrounded by a trench which serves as culture for fish. Oryza sativa (FARO 49) was planted in nursery bed and transplanting was done after 15 days at a spacing of 10cm by 10cm. Rice growths were accessed by measuring morphometric variables: plant height and leaves as well as reproductive stage: yield throughout productive period. Pond water quality and sediment nutrient accumulation were monitored. Rice plant height measured after sixteen weeks was 146.98±11.65cm and yield recorded was 2666.7kg/ha. Water quality parameters such as pH, temperature, dissolved oxygen, NO_3-N, NO_2-N and NH_3were within recommended range; showed a significant difference through improved physical-chemical parameters and revealed NO_3-N, NO_2-N and NH_3 are strongly correlated positively and significant to rice growth. There was significant different ($p > 0.05$) during production between rice plant and nitrogen content present in soil. Sediment accumulated showed high nutrient received and manure with supplementary feed. The results showed that patterns of pond water and nutrient flows were strongly influenced by fish farming activities. Hence, integrating fish pond with crop has strengthened nutrient recycling which enhanced better farm outputs and safeguard the environment.

Keywords: Productivity; Rice plant, Aquaculture; Agriculture

INTRODUCTION

Aquaculture continues to grow rapidly, and this influence the industry output yearly (FAO, 2012). It was described as a growth industry striving to satisfy a growing market and currently one of the fastest growing sectors of agriculture in Egypt (Nhan *et al*., 2007). Growing public demand for healthy, tasty and affordable food is stimulating the "boom" in this industry. Globally, aquaculture has become the fastest growing food production sector involving animal species. This tremendous growth has provided a number of opportunities for greater food security, improved livelihoods and reduced poverty (FAO, 2007).

Integrated aquaculture strategies could be regarded as an option for efficient utilization of available resources, waste recycling, energy saving and maintaining ecological balance and circulation in aquaculture subsystem (Omitoyin, 2007). It has been known to advocated increase land use efficiency under increased population growth, environmental degradation, land and water scarcity (Barg *et al*., 2000). This system is a sustainable farming system known for diversification of agriculture towards nutrient linkages through interconnected flows of nutrients in aquaculture components while reducing environmental impacts (Prein, 2002).

According to Edwards, (1998) the nutrient linkage makes use of off-farm bio-resources originating from another farm agro-industrial activities contributing to farming intensification, efficient use of natural resources, food security, income generation, environmental protection and sustainable agriculture (Devendra and Thomas, 2002).The integrated pond sub-system is made possible with existing farming activities to maximize production while minimizing nutrient discharges (Nhan *et al*., 2007). Potential benefits from integrating aquaculture in farming systems include: enhanced employment, income generation through additional or off-season production, food security, availability of high-value protein food, promoting organic farming through sustainable production and environmental protection. Sustainable aquaculture depends upon eco-friendly and economically and socially viable culture systems which offers tremendous potential for food security and poverty alleviation (Lemma *et al*., 2015).

Integrated ponds are nutrient traps, as a high proportion of added nutrients accumulate in the sediments (Boyd and Gross, 2000) and this prevents from flowing into drainage waters (Olapade *et al*., 2015). These agricultural wastes; livestock manure, waste water can be used to fertilize vegetable crops and to restore soil fertility (Gabriel *et al*., 2007). The recycling of organic wastes for fish culture serves the dual purpose of cleaning the environment and fertilizers. Soil fertility improvement and control with less use of chemical Furthermore, the outputs of the pond optimization is multiple, including nutrient recycling and accumulation, nutrient and water use efficiency, and environmental sustainability rather than only aquatic production or pond profitability.

The fish farm supplies not only enough fertilizer to produce a large quantity of fish, but also produces meat, vegetable, etc as it fully utilizes the water body, the water surface, the land and the pond to increase the food available for human consumption. For human to enjoy these resources, there is need to switch from consumptive to recyclable and sustainable use of the finite resources nature richly endowed us, which offers tremendous potential for food security and self-sufficiency. It is based on the concept that 'there is no waste' and waste is only a misplaced resource which can become a valuable material for another product (Luu *et al*., 2002; Pekar *et al*., 2002).

Aquaculture- agriculture is consequently facing some challenges of producing more food for this growing population, conserving the environment and ensuring food security (Godfray *et al*., 2010). However, the sector's growth threatens its ability to continue to provide increasing yield in a sustainable manner and concerns with the ecological damage resulting from fish farming. The objective is to increase farm productivity through maximized synergies and minimized antagonisms between components there by increasing the contribution of aquaculture to economic growth.

Study Area

The experiment was conducted at the fish farm, University of Ibadan, Ibadan, Nigeria. The research was conducted for 16 weeks at the integrated pond with surface area of 227.5m^2. The fish trench has an area of 178m² and the rice paddy with an area of 49.5m^2 with depth 0.4m.

MATERIALS AND METHODS:

Lowland FARO 49 (*Oryza sativa*) rice seeds were placed in nursery beds and covered with compost. The beds were kept damp until germination after 15 days at 2-leaf stage. Transplanting of seedlings into properly tilled soil of rice paddy at a spacing of 10cm intra and 10cm inter rows, planted in lines. Water in the integrated pond was kept minimum and maintained during vegetative growth period. Weed was manually removed frequently. Rice growth was accessed by measuring morphometric stage: plant height, leaves as well as reproductive stage: yield throughout productive period performed according to IRRI (2002). Culture water samples were collected at two different locations from integrated pond between 8 - 9am. Samples were collected bi-weekly in clean plastic bottles and taken to laboratory for physic-chemical analysis. Water quality parameters measured were Dissolved oxygen, pH, ammonia (NH_3), nitrate (NO_3-N), nitrite (NO_2-N), hardness and alkalinity. These parameters were determined by using PONDLAB 200 kits in line with standard methods APHA (1995).

The water quality temperature was monitored the same time using thermometer at 20 cm below water surface. Soil samples were collected at two different sampling points, A and B from the rice paddy at a depth of 10-15cm; initial and final sampling of the study. The soil nutrients were analysed using LaMotte garden soil test kit Model EL and in the Laboratory to determine the nutrients. Chemical analysis was done for the following parameters of the soil, Nitrogen, phosphorus, potassium, pH and Total organic carbon. Two physical properties of the soil; the particle size (texture) and bulk density were also determined and measured in the laboratory.

Statistical analysis

Correlation and regression were carried out. Correlation coefficients investigate relationships of rice growth and water quality and nutrient data.

RESULTS

The results of the water quality parameters evaluated in this study are presented in Table I. Mean water temperature records 28.03±1.03℃ from observation this was within the recommended range Boyd, (1998). pH value of 7.2±0.44 range with moderate fluctuations and was in line with the recommended range according to Omitoyin, (2007). The desirable range for pond pH is 6.5 - 9.5 and acceptable range is 5.5 - 10.0 (Ajani *et al*., 2005; Boyd and Tucker 1998). Ammonia concentration ranged within 2.75±2.32mg/l, remained low (0.2mg/l) within week and increased towards the end of the rearing cycle. Ammonia peak was observed on the ninth week of the rearing followed by increase in nitrite-nitrogen, this suggests that the system established nitrification process. Mean nitrate-nitrogen recorded 6.40±3.60, there was a strong positive correlation between rice growth and nitrate-nitrogen r=0.9794. Increase in rice growth correlated with increase in the rating of nitrate nitrogen. Mean nitrite-nitrogen records as 0.66±0.4 and showed an increasing trend in the later part at 1mg/l from observation it was above the recommended range which could be due to little/no water exchange during study period. There was a positive correlation between rice growth and nitrite-nitrogen r=0.9653. The mean value of alkalinity and hardness ranges between 135.16±9.97mg/l and 140.84±12.14 mg/l respectively as shown in table 1. The alkalinity and hardness of pond water varied with mean value of 135.16±9.97mg/l and 140.84±12.14 mg/l respectively. The mean values for the acceptable and recommended range of water quality in integrated culture are recorded and showed Table II. Rice growth analysis (figure I) shows a significant difference through improved physical-chemical properties of rice paddy. The results of rice growth stages observed in this study are presented in Table IV. The plant height in the experimental plot ranged from 8 to 158cm after transplanting. The number of leaves ranged from 2 to 11 with a total rice strand at 1034 cm at the end of production. Total yield recorded 15.2kg/49.5m^2 from the experimental study. Rice growth analysis shows a significant difference through improved physical-chemical parameters in integrated pond culture. The study revealed that ammonia, nitrate-nitrogen, nitrite-nitrogen are strongly correlated positively and thus significant to rice growth. pH is said to have a low correlation; the relationship between rice growth, dissolved oxygen and temperature had negative correlation hence not significant. There was significant different ($p > 0.05$) during production between rice plant and nitrogen content present in soil. The yield from integrated pond shows an additional nutrient from fish feed and faeces which aids in nutrient recycling and also play an important role in improving the soil health, it can act as a buffer in water nutrient concentration in minimizing loss from the system. Mean Total nitrogen concentration was recorded as 12.2±3.7mg/kg at initial stage. The nitrogen concentration in rice paddy before transplant ranged between 8.5-15.7mg/kg followed by an increased during the study period at the final stage ranged between 2.9-25.3mg/kg as shown in table III. This was also in line with Lani *et al*., (2013) for the recommended range for cultivation of rice.

Available phosphorus concentration in paddy fluctuate before and after during the period of study as shown in Table III. Mean phosphorus concentration in rice paddy before transplant was 9.52±14 mg/kg showed a decrease during the rearing period at the final stage was 2.39±0.3mg/kg. Phosphorus obtained in this study showed no significant difference ($p<0.05$) and it was seen that there was a positive relationship.

Mean potassium concentration in rice paddy before transplant recorded 31±42mg/kg showed an increase during the rearing period and decrease during study as shown in table III. Mean nitrogen concentration was recorded at the final stage records 17±28.3mg/kg, Potassium concentration showed sharp decline and surge throughout the study period at the end of rearing cycle. The potassium recorded in integrated production system through the period of experiment study showed significant difference ($p>0.05$). On the whole, the mean soil nutrients recorded in this study were within the range at early rearing stage reported by Nwilene *et al.*, (2008) for optimum growth and rice production.

Organic carbon concentration was recorded as 1.03±0.1/kg over the study period as shown in table III, organic carbon concentration in rice paddy before transplant followed by a decline toward the end of the rearing cycle. Organic carbon contents translate to organic matter contents in the soils. The organic matter present in rice paddy before transplant and at harvest was 0.80±0.7mg//kg; it showed a steady increase and decline towards the rearing cycle.

Table 1: Physico chemical parameters of water in Integrated Fish pond

Parameters	Weeks				
	1	4	8	12	16
Temp °C	29.0	29.0	28.0	27.5	27.0
pH	7.0	8.0	7.0	7.0	7.0
DO (mg/l)	6.0	5.5	4.8	6-0	5.0
NH_4 (mg/l)	0.2	0.2	2.5	3.5	3.5
NO_2-N (mg/l)	0.25	0.25	0.5	1.0	1.0
NO_3-N (mg/l)	2.5	2.5	5.0	10.0	10.0
Alkalinity (mg/l)	124.6	133.7	124.6	133.7	142.4
Hardness (mg/l)	142.4	160.2	142.4	133.7	124.

Abbreviations**:** Temp-Temperature; DO- Dissolved Oxygen; NH4-Ammonia,NO2-N- Nitrtrite Nitrogen, NO3-N- Nitrate Nitrogen; mg/l- milligram per liter; °C- Degree Celsius

Table II: Mean values of water quality parameters in Integrated Fish cum Rice culture pond.

Parameter	Mean values	Range Obtained	Acceptable range
Dissolved Oxygen (mg/l)	5.13±1.04	4.0-7	4.0-6.0
Temperature (°C)	28.03±1.03	23-32	20-32
Ammonia (mg/l)	2.75±2.32	5-0.5	0.02- 0.03
Nitrate - nitrogen (mg/l)	5.40±2.60	8- 2.8	2-2.5
Nitrite - nitrogen (mg/l)	0.66±0.36	1.0-0.3	0.2-0.5
Alkalinity (mg/l)	135.16±9.97	145-125	79-80
Hardness (mg/l)	140.84±12.14	128-152	79-81
pH	7.2±0.44	6-7	6-8

Source Boyd, 1998; 2007 and Omitoyin, 2007

Table III: Rice paddy soil characteristics and nutrients in Fish cum Rice and Pig production system.

Parameters (units)	Before cultivation (initial)	Final
Texture:		
Sand (%)	84.2	83.6
Silt (%)	12.4	7.0
Clay (%)	3.4	9.4
Texture	Loam	Loam
Organic carbon (mg/kg)	1.03±0.1	0.80±0.7
Organic matter (mg/kg)	1.77±0.2	1.37±0.2
Total nitrogen (mg/kg)	12.2±3.7	11.2±14.1
Available phosphate (mg/kg)	9.52±14	2.39±0.35
Potassium (mg/kg)	31±42	17±28.3 3
pH (mg/l)	6.5±0.1	6.7±0.2 5

Source: African Rice Center (WARDA)

Table IV: Mean production indices of Rice paddy in integrated production system

Production (units)	Initial	Final
Mean height cm	10.12±2.12	146.98±11.65
Mean leaves (n)	2.39±0.49	9.16±0.62
Rice strand/49.5m^2	1058	1034
Yield (kg/49.5m^2)		15.2
Yield (kg/ha)		2666.7

Abbreviations: cm- centimeter meter; n- number; m^2- meter square, kg- kilogram; ha- hectare

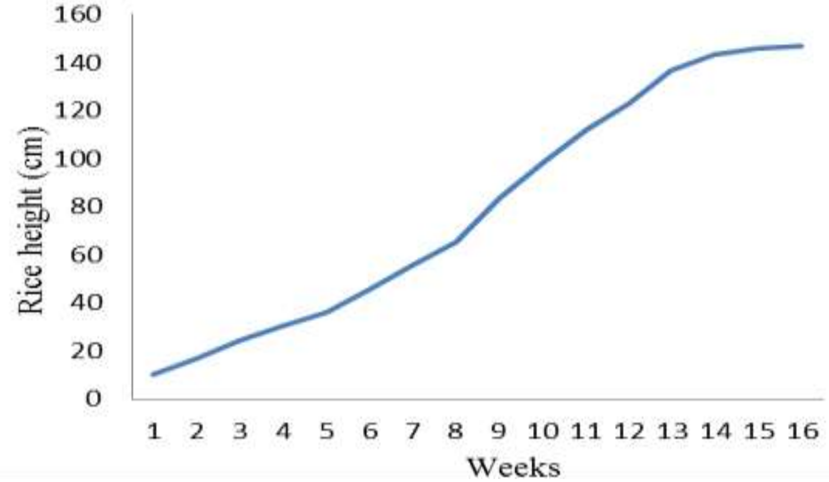

Figure 1: Weekly mean height of rice in integrated production system

DISCUSSION

Physic-chemical characteristics of water play an important role in regulating the various activities. These parameters are essential for the better survival and growth of fish. Water temperature fluctuation may be due to surrounding water/air temperature and shading by rice plants which also maintains the water favourable for activities (Kunda *et al*; 2008). Desta *et al*., (2015) reported that the optimal water temperature for rice field was also similar to the findings. pH evaluated recommended range all through the rearing cycle, thus good pond productivity (Fafioye *et al*,2005. Manure and urine raise the pH level and accelerate the decomposition of organic matter and activity. Pond CO2 concentrations and pH, are affected by respiration and photosynthesis. Carbon dioxide is released during respiration and consumed for photosynthesis. As a result, pond pH varies throughout the day, the plant members of the pond plankton community, phytoplankton, absorb CO2 for photosynthetic production of sugar. Dissolved oxygen fluctuates with a mean value of 5.13±1.04mg/l. The dissolved oxygen recorded was in agreement with the optimum range of dissolved oxygen 4.0 to 6.0 mg/l (Omitoyin, 2007, Ajani *et al*., 2005). The higher level of dissolved oxygen recorded may be as a result of photosynthetic activities by primary producers during the day when light intensity is high, and probably the reason for low dissolved oxygen recorded in the morning may be due to respiratory activities of aerobic organisms in the culture medium. According to Wahab *et al*; (2008) dissolved oxygen support good production in agreement with period of study and also essential for growth of bacteria which decompose organic detritus and release of nutrients which is shared by the paddy. It was observed high level of dissolved oxygen may be as a result of Photosynthesis activities by phytoplankton and lowest probably due to decomposition and feed remains. Ahmed *et al*. (2010) stated Perturbation of the soil leads to high dissolved oxygen needed for the nutrient cycling by the soil microorganisms.

Water quality recorded in this study conformed to the recommendation by Omitoyin, (2007) except Ammonia which was high; this could have been as result of high waste product due to low water exchange. However, the ability to withstand periods of high ammonia level during the experiment agrees with the findings of Boyd and Lichotkoper (1985) that *Clarias* species can live in water with slightly high ammonia level. Increase in rice growth correlated with increase in the rating of nitrite-nitrogen. The values recorded in this study were higher than values reported by Omitoyin, (2007). This resulted from the fact that the pond was fertilized and high biological activities in the water perhaps causing increase in nitrite values. This agrees with the observation reported that the inorganic loading affects biological activities in pond water. Nitrate-nitrogen, Nitrite-nitrogen and Ammonia concentration fluctuated largely and records high values. This may be as a result from high biological activities with inorganic loading in pond water as result of low water exchange in the presence of bacteria, dead phytoplankton, decaying organic matter, accumulation of left-over protein-rich feed accumulate in the system which may support growth and yield of rice (Rukera, *et al*., 2011). The reported alkalinity in this present study is within the acceptable range for aquaculture practice (Boyd and Tucker 1998: Adebayo and Adesoji, 2008). A total alkalinity of at least 20mg/l is necessary for good pond productivity. The values obtained in this study are appreciable and fall within desirable range (Boyd and Tucker 1998). According to Nwilene *et al*. (2017) the concentration is in the same range of concentration during the study period. Nitrogen concentration increased trend in the later part of the study, which showed highest concentration at the final stage. This can be due to the nutrient accumulation from ammonia present in water. The nitrogen value recorded in integration production system throughout the period of the experiment showed significant difference ($p>0.05$) and it was seen that there was a strong positive relationship. On the whole, the mean soil nutrients recorded in this study were within the range reported by Nwilene *et al.*, (2008) for optimum growth and rice production.

This variation in organic matter in soil influence physical, chemical and biological properties of soil such as soil texture, water retention, nutrient content and retention and microbial activities in soil (Frei *et al*., 2007). The application of livestock manure increases soil organic matter content, and this leads to improved water infiltration and water holding capacity as well as an increased cation exchange capacity. Rasowo *et al*., (2008) reported that manure and urine raise the pH level and accelerate the decomposition of organic matter and activity.

The rice paddy pH values ranged from (slightly moderate acidic) to (neutral soil reaction) with a mean pH of 6.5±0.1 as observed in table III. The optimum soil pH for rice production is 5.5 to 8 (Landon, 1991); ph values remained within the recommended range all through the rearing cycle. The pH value before planting was 6.45 and at the last planting season pH was recorded as 6.74. The pH value obtained in this study showed significant difference ($p>0.05$) and it was seen that there was a positive relationship. It is reported that cultivation of rice is even possible with the ph up to 9.0 but high pH values of the soil could negatively influence the availability of the micronutrient as well phosphorus (Kajiru *et al*., 2015). On the whole, the mean soil nutrient recorded in this study as shown in table III was within the range reported by Nwilene *et al.*, (2008) for optimum growth and rice production at the early stage of planting. Rice plant being a demanding crop, the observed plant available phosphorus value would satisfy the phosphate demand by the rice. In addition, the availability phosphorus in rice paddy is a function of soil pH (Inusa *et. al*., 2013; Kajiru *et al.*, 2015). Hence the availability of the soil phosphorus may be negatively affected by the high pH values of the soils.

Plant height measured may be influenced by external factors; status of soil fertility, also increase may be due to improved nutrient availability resulting from the excrement produced by fish as well as to aeration of the growth medium as the fish moved around (Rasowo *et al*., 2008). The seedlings after transplant showed best growth rate and no record of disease or pest attack on the plants known as the effective method of biological control of insect pests, weeds and diseases Nhan *et al*., (2007). The rice plant has long panicle, high tillering rate, more grain and less number of empty grains as against rice monoculture (Ahmed *et al*., 2010). The present study reveals an increase in rice and straw yield than monoculture due to the high number of tillers developed on the plants which resulted in an increase in the total biomass of the plants (Ahmed *et al*., 2010). Rice-fish culture gave significantly higher yield this could be attributed to the more favorable growing conditions.

The nature of soil component was measured during the paddy growing period. The composited soil samples in the rice fish field after 16 weeks of culture period showed increase in the amount of silt and reduction in clay content in line with (Kajiru *et al*., 2015; Frei *et al*. 2007). In this study the textual classes of the soil ranged from sandy clay loam to loamy sand. It has being recorded that clay content is suitable for rice production because of their capacities to retain plant nutrient and soil water (moisture) these high clay content restrict the percolation of water through soil hence encouraging ponding of bunded fields (Kajiru *et al*., 2015). Thus extends and improve the water use efficiency of the harvested rainwater by the rice plant.

CONCLUSION:

In order to meet the soaring demand for food, there is a need to increase Integrated Aquaculture -Agriculture. This study concludes that integrated farming could be a viable option for diversification there by ensuring food security and poverty alleviation. Integrated rice-fish increases rice yields there by established the relationships between pond management practices and pond nutrient accumulation and environmental impacts through strengthening nutrient recycling between component enhancing farm outputs for consumption all year round. This can be done through environmentally sustainable system in terms of resource utilization, diversity, productivity and efficiency. In addition integrated farming system can reduce the nutrient loss through pond effluent and thus minimize the environmental impact. However effect of water quality is related to the level of nutrient present in culture water. The rice growth performance were influenced by the levels of accumulation present in the soil which may be attributed to variability in water quality and extend of cultured fish. Therefore it can be concluded that fish culture water can be used as an appropriate nutrient input for standard organic fertilization for rice growth in production of Integrated Aquaculture-Agriculture. Based from the findings and conclusions of this study regular soil testing should be conducted to monitor soil fertility level of rice primarily for nitrogen, phosphorus and potassium levels.

ACKNOWLEDGEMENT

The author greatly acknowledged CORAF/WECARD Research Project team who through Poverty Eradication and Grassroots Empowerment through Sustainable Integrated Aquaculture Development: supported this adaptive research at the Department of Aquaculture and Fisheries Management, University of Ibadan in conjunction with West and Central African Council for Aquaculture Research and Development (WECARD).

REFERENCES

Adebayo, I. A. and Adesoji, S. A. (2008). Comparative Assessment of the Profit Margin of Catfish Reared In Concrete Tank And Earthen Pond. *African Journal of Agricultural Research* 3(10): 677-680.

Ahmed, N., Alam, M. F., and Hasan, M. R. (2010). The Economics of Sutchi Catfish Pangasianodon Hypophthalmus) Aquaculture under Three Different Farming Systems in Rural Bangladesh. *Aquaculture Research,* 41: 1668–1682.

Ajani E.K., Akinwole A.O, and Ayodele, I.A. (2005). Fundamentals of Fish Farming in Nigeria. Walecrown Publishers Ibadan. Pp. 158. ISBN 978-245-543-1

America Public Health Association, (1995).APHA. Standard Methods for the Examination of Water and Wastewater 19th Edition. APHA, Washington, DC 1108pp.

Barg, U., Bartley, D., Kapetsky, J., Pedini, M., Satia, B., Wijkstrom, U. and Willmann, R. (2000). Integrated Resource Management for Sustainable Inland Fish Production. FAO Aquaculture Newsletter 23, 4-8.

Boyd, C. E. and Lichtkoppler F.R. (1985) Water Quality Management in Pond Fish Culture, Resource development service: No 22 Auburn University Aubum Alabama, 345p

Boyd, C.E. and Tucker C.S. (1998):. Pond Aquaculture. Water Quality Management. Kluwer Academic Publishers, Boston, Massachusettes, pp.700

Demaine, H. (Eds.), Rural Aquaculture. CABI publishing, Wallingford, pp. 55-75. Devendra, C. and Thomas, D., 2002. Crop-Animal Systems in Asia: Importance of livestock and Characterization of Agro-Ecological Zones. Agric. Syst. 71: 5-15.

Desta L, Prabha D, V. Sreenivasa and Getaun A (2015). Performance Evaluation of Paddy and Fish Integrated Farming at Dambi-Gobu Micro Watershed at Bako, West Showa, *and Ethiopia Advanced Journal of*

Agricultural Research. Vol. 3(02), pp. 013-021.

Edwards, P., 1998. A system approach for the promotion of integrated aquaculture. *Aquaculture. Ec. Management*. 2: 1-12.

Fafioye, O.O, Olurin, and Sowunmi, A.A. (2005).Studies on the Physicochemical Parameters (7 days variation) of a Major Water Body of Ago-lwoye, Nigeria. *J Aquatic Sc*. pp 121

FAO (2007).The State of World Fisheries and Aquaculture .FAO Fisheries and Aquaculture Department. Food and Agricultural Organization of the United Nations, Rome, Italy.162 pp.

FAO, (2012).Investing in Agriculture for a Better future, the Stare of World Food and Agriculture 2012. 45pp

Gabriel, U. U.1, Akinrotimi, O. A., Bekibele D. O., Anyanwu, P. E. and Onunkwo D.N. (2007).Economic Benefit and Ecological Efficiency of Integrated Fish Farming in Nigeria. *Scientific Research and Essay* Vol. 2 (8), pp. 302-308

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad L., Lawrence, D. and Muir, J. F., (2010). Food Security: The challenge of Feeding People. Science 327(812):812-818.doi:10.1126/science.

International Rice Research Institute (IRRI), 2002. Maclean, J. l., Dawe, D. C., Hardy, B. and Hettel,G. P. International Rice Research Institute Rice Almance. CABI Published. ISBN 0851996361

Kunda, M., Azim, M.E., Wahab, M.A., Dewan, S., Roos, N. and Thilsted, S.H. (2008). Potential of mixed culture of freshwater prawn (Macrobrachium rosenbergii) and self recruiting small species mola (Amblypharyngodonmola) in rotational rice-fish/prawn culture systems in Bangladesh. *Aquaculture Research* 39:506-517

Lani, I., Ruben, P, T., Roberto, B., Barba, Jr. and Nicca, A. M. (2014). Soil fertility and Evaluation for Rice Production in Catanduanes Province, Philippines. *International Journal of Scientific and Technology Research.* Vol3: 12

Lemma. L, Devi. P. L., Sreenivasa. V., and Getaun, A. (2015). Performance Evaluation of Paddy and Fish Integrated Farming at Dambi-Gobu Micro Watershed at Bako, West Showa, *Ethiopia. Advanced Journal of Agricultural Research*.Vol. 3(02), 13-021p.

Luu, L.T., Trang, P.V., Cuong, N.X., Demaine, H., Edwards, P., Paint, J., 2002. Promotion of small-scale pond aquaculture in the Red river delta, Vietnam. In: Edwards, P., Little, D.C.,

Nhan, D. K., Phong, L. T., Verdegem, M. J. C., Duong, L. T., Bosma, R. H., and Little, D. C. (2007). Integrated Freshwater Aquaculture, Crop and Livestock Production in the Mekong Delta, Vietnam: Determinants and the Role of the Pond. Agricultural Systems, 94, 445–458.

Nwilene F.E., Oikeh S.O., Agunbiade T.A., Oladimeji O., Ajayi O., Sié M., Gregorio G.B., Togola A. and A.D. Touré (2008). Growing Lowland Rice: A Production Handbook. Africa Rice Center (WARDA). Pp14-38.

Nwilene, F. E., Stout, M. J., Hadi, B. A. R., Freitas, T. (2017). Rice Insect Pest and their Mangement. ISBN 9781786761965

Olapade Olufemi Julius, Alimamy Turay, Momoh Rashid Raymond (2015). Economic Assessment of Integrated Fish Farming (Fish-Rice-Piggery) in Sierra Leone. Agriculture, F*orestry and Fisheries*. Vol. 4, No. 3, 2015, pp. 87-94.

Omitoyin, B.O. (2007). Introduction to Fish Farming in Nigeria. Ibadan University Press, University of Ibadan, Nigeria, pp. 35-40.

Pekar, F., Be, N.V., Long, D.N., Cong, N.V., Dung, D.T., Olah, J., 2002. Eco-technological analysis of fish farming households in the Mekong Delta, Vietnam. In: Edwards, P., Little, D.C., Demaine, H. (Eds.), Rural Aquaculture. CABI Publishing, Wallingford, Oxon, pp. 77-95.

Prein, M. (2002). Integration of aquaculture into crops-animal systems in Asia. Agricultural system 71, 127-146.

Rasowo. J., Auma. E., Ssanyu. G., and Ndunguru. N. (2008). Does African Catfish (Clarias gariepinus) Affect Rice in Integrated Rice-Fish Culture in Lake Victoria Basin, Kenya. *African Journal of Environmental Science and Technology* Vol. 2 (10). pp. 336-341

Rukera T.S., Mutanga , 1, O., and Micha J.C. (2011). Optimization of an Integrated Rabbit Fish-Rice System for Sustainable Production in Rwanda. Rwanda Journal, Volume 24 Series E: *Agricultural Sciences*. pp1259–1276

Wahab, M.A., Kunda, M., Azim, M.E., Dewan, S. and Thilsted, S.H. (2008). Evaluation of freshwater prawn-small fish culture concurrently with rice in Bangladesh. *Aquaculture Research* 39:1524-1532 .