THE AQUACULTURE POTENTIAL OF WETLANDS IN NIGER STATE, NIGERIA, WEST AFRICA

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SUMMARY

The appropriateness and feasibility of commercial fish farming at village level in Niger State, Nigeria, was assessed. Culture of *Oreochromis niloticus* and *Clarias gariepinus* in ponds was never feasible, regardless pond size and intensity level. Introduction of fish farming is only possible in situations where large water surfaces are created at minimal costs, and when the input level is low. These conditions are met by culture based fisheries in the ox-bows of the floodplains and by extensive aquaculture in small dam reservoirs in stream flow valleys. Culture based fishery must be regarded as an improvement to the present capture fishery. In situations where small dam reservoirs cannot be drained, culture based fisheries can be applied, be it with more inputs, as small reservoirs are easier to manage than ox-bows. Reservoirs which can be drained can be considered as a type of fish pond. Pond farming in such dam reservoirs is the next logical step in the transition from hunting for fish (capture fisheries) to the implementation of environmental controlled husbandry and farming systems for aquatic animals. In the future more intensive aquaculture farming systems could be propagated.

INTRODUCTION

In the humid and sub-humid parts of West Africa, the total wetland area covers roughly 600,000 km². In addition to inland swamps and estuaries, three types of wetland can be distinguished: *river floodplains* (large floodplains) covering 54,000 to 129,500 km² (2.5 to 5.9% of the land surface); *overflow valleys* (small floodplains) covering 80,000 to 194,000 km² (3.6 to 9.0% surface); and *streamflow valleys* (small inland valleys) covering between 101,000 and 218,000 km² (4.4 to 10.0% surface) (Hekstra and Andriesse 1983).

Wetlands form a major food production resource for Africa and their possible development and utilization have extensively been studied mainly in view of water management and technologies that will enable small farmers of the region to cultivate the valleys more intensively. Thereby water has been regarded as a manageable input factor in agriculture, however, water can also be regarded as a food resource in its own right. This study investigated the possibility to augment fish production in the wetland area, in view of the physical properties of the region and considering the traditional role of these wetland as a food production resource.

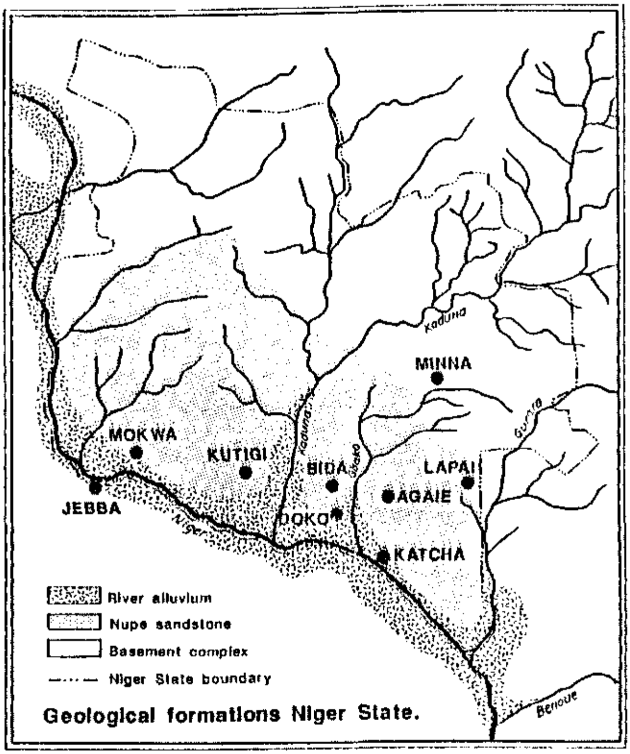

Figure 1. Geological formations in Niger State, with overview of important populations centers and rivers in the study area. Source: Hekstra et al. 1988.

METHODS

As study target area, the Southern Part of Niger State, Nigeria (Figure 1), has been chosen, the region being regarded as representative with respect to present land and water use in inland valleys on depository formations in the sub-humid parts of the West African Wetlands. The authors of this article, covering the disciplinary fields of aquaculture, fisheries biology, hydrology and socio-economics, spent in total one man-year in the study area. Numerous visits were paid to Federal/State Governmental Agencies, Research Institutions, and private enterprises, and field trips were made throughout the study area. Interviews were held with a large variety of persons: diplomats, governmental officials, scientists, entrepreneurs, fish sellers, fish consumers, villagers, and farmers. Fisheries and aquaculture practices were analyzed in depth, with special attention being given to the physical and socio-economic properties of the culture environment.

Table 1. Climatological data for Bida. Alt. 138 m. Lat. 9.15 N, longit. 6.05 E. Source: Gunneweg (undated)

	J	F	M	A	M	J	J	A	S	O	N	D	Yr
Average rainfall (mm)	4	66	24	71	145	165	221	204	237	96	6	2	1,179
Evaporation (Epan mm)	131	142	181	169	161	143	128	118	126	148	143	133	1,721
Min. monthly temp. (°C)	20.8	23.0	25.0	25.0	23.8	22.6	22.3	22.2	22.0	22.1	21.2	20.2	22.
Max. monthly temp. (°C)	33.8	35.6	36.4	35.2	32.6	30.1	31.4	29.6	30.2	23.3	34.6	34.6	32.
Mean monthly sunshine hrs.	6.5	7.2	7.4	7.4	7.4	7.3	5.4	3.8	5.4	7.3	8.6	7.9	6.8

To determine a reliable estimate of the economic feasibility of fish farming in ponds in the study area, cost-benefit analyses of different fish farming scenarios were made:

- Low intensity fish farming (no feeding, application of fertilizer) in ponds with polyculture of *Clarias gariepinus* and *Oreochromis niloticus* during an eight month production cycle (3-4 MT/ha).
- High intensity fish farming (good quality feed, fertilizer) in ponds with mono-culture of *Clarias gariepinus* during an eight month production cycle (10 MT/ha).

Prices for inputs were valid December 1987, and are given in Naira (N). The exchange rate was 3.7 N per US$. Fixed costs included pond construction and equipment. The investment was depreciated over a 10 year period and the interest rate used was 20%. The operational costs include pond preparation (disinfection, liming and fertilization), fingerling stocking (purchase and transport) and farm operation (fertilization, feeding, harvesting, marketing and daily attendance). A detailed breakdown of the costs involved can be found in the mission report submitted by the study team (Hekstra et al. 1988).

Both scenarios were tested for a 0.02-ha, manually constructed pond, and for a 10-ha mechanically constructed pond. As fish farming in either scenario resulted in a net loss, alternative scenarios for the introduction of fish farming, which are adapted to the physical and socio-economic environment, were proposed.

RESULTS: PHYSICAL ASPECTS

Geology

The southern part of Niger State belongs to the Niger/Benoue trough in which Cretaceous sediments are predominant. The country is gently undulating and is underlain by Nupe Sandstone (Fig. 1.), which has undergone several

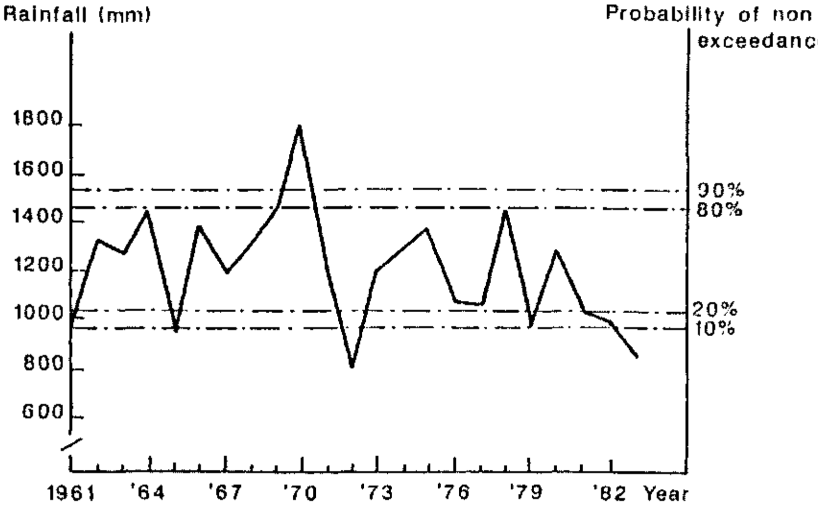

Figure 2. Yearly total rainfall in Bida. Source: Gunneweg, undated.

weathering cycles, leaving mainly quartz behind. This area is very sandy and pervious. The northern part of the study area is covered with Pre-Cambrian Basement Complex (Fig.1.). Here, rocks are mainly from metamorphic or igneous material, with granites, gneisses and migmatites being typical. The floodplains of the rivers Niger, Kaduna, Gbako and Gurara consist of alluvial deposits (Fig.1.). The sediments, which are stratified, are derived from Basement Complex and Nupe Sandstone. The texture of the strata ranges from coarse sand to clay, the former being predominant.

Climate

In the study area, rainfall decreases from North to South and from East to West. There is a distinct mono-modal rainy season (Table 1.). The average annual rainfall in Bida, located centrally in the study area, is about 1,200 mm (Kowal and Knabe 1972). There is a 20% (once every 5 years) and 10% (once every 10 years) probability, that the annual rainfall will not exceed 1,025 and 970 mm, respectively (Fig. 2.). The duration of the rainy season differed 110 days between the 20 and 80% non-exceedance levels of annual rainfall (Table 2.). This variation is mainly due to the delayed start of the rainy season in dry years (Table 2.).

Inversely to rainfall, evaporation increases from East to West. In Bida, once every 5 years, the rainfall in every 10-day period is insufficient to compensate for pan evaporation (Figure 3.). The average annual pan

Table 2. Variation of the start and duration of the rainy season in Bida. Source: Gunneweg (undated).

Recurrence period	Start rainy season before day nr.	Minimum duration rainy season (days)
1 out of 5 years	99	210
4 out of 5 years	165	100
difference (days)	66	110

average annual rainfall. The evaporation from a stagnant water is expected evaporation in Bida is 2,149 mm (Gunneweg undated), or 1.75 times the to be in the same order of magnitude. In addition, peak evaporation in march/april coincides with low availability of surface water (Gunneweg undated).

Hydrology

The river density in the study area is low, mainly due to the coarse texture of the soils, causing rain water to infiltrate quickly and thus preventing surface water run-off. Therefore, seepage water entering the valley bottom is the main water source in rivers.

Stream flow valleys have on average surface water 7 months per year, but this reduces to 2 months once in 5 years (IITA 1986). In some instances, small dam reservoirs were built. From these reservoirs, water is channeled through peripheral channels along the fringe of the valley bottom, to the fields (mainly rice). Reservoirs on Basement Complex hold water longer than on Nupe Sandstone.

Most river overflow valleys have perennial water in the downstream reaches, which can be diverted at reasonable cost. The water supply to existing irrigation schemes in the study area always originated from overflow valleys.

Water levels of river floodplains fluctuate between 5 and 7 m annually (Hekstra et al. 1988). The lowest levels occur March through May, and the peak levels fall between August and October, at which moment the whole floodplain can be covered by 3 to 5 m of water. On the Niger and the Kaduna flooding occurs irregularly, due to release of water from hydropower dams located upstream.

Numerous lakes, that hold water the whole year, are scattered throughout the floodplains. The majority of these lakes are ox-bows, old meanders of former river beds. These lakes are intensively fished during the dry season by the farmers from nearby villages.

Soils

Upland soils comprise more than 90% of the study area. The basic infiltration rate ranges between 2 and 5 mm per hour (Erinne and Olorunpomi 1987). In consequence, soils are too permeable for pond construction.

Valley bottom soils cover 2 to 4% of the area. In general, in stream flow valleys the texture is coarse, whereas in overflow valleys and river floodplains large areas have higher clay contents, allowing the construction of fish ponds. However, as slopes are small, it will be necessary to build long supply and drainage channels.

The valley fringes constitute the transition from the upland to the lowland. They cover some 6 to 8 % of the area. Generally, these soils are coarse to medium sands and highly permeable. Close to the valley bottom, groundwater

Table 3. Fish production in Niger State. Source: Hekstra et al. 1988.

Year	Capture (MT)	Aquaculture (MT)
1982	16,500	3.0
1983	20,000	4.2
1984	17,000	5.0
1985	18,300	7.5
1986	21,000	9.0

depth is $\leq$ 1 m during part of the year. Here ponds could be dug partially into the groundwater table, and be supplied with water from an upstream dam reservoir. However, such ponds will hold water only during 6 to 7 months per year, and productivity will be low due to loss of nutrients through seepage. Similar conditions apply to the soils in stream flow valleys.

FISH CULTURE AND FISHERIES

Fish production

In 1986, total capture fish production in Niger State was 21,000 MT, the majority of the fish being harvested from the Niger-Kaduna River system (Table 3). In contrast, aquaculture production only accounted for 0.04% (9 MT) of the total fish production in Niger State. The most important species cultured are *Oreochromis niloticus* and *Clarias gariepinus*. Few ponds could be drained completely, and none of the barrage ponds visited had the pond bottom cleared and leveled, making seining impossible. Some ponds were abandoned, major causes being low production, bad construction, insufficient fingerling supply and/or lack of funds.

Water quality

Surface water temperatures in the study area ranged between 28-30°C. The pH varied between 6.0 and 6.6 with a methyl orange alkalinity of 0.5 ml HCl/l, indicating liming is necessary. When monitored, the concentrations of PO_4-P and NO_3-N in surface waters, were extremely low, 0.01 and 0.40 ppm, respectively. Even in fish ponds, that received small quantities of fertilizers through feeding, concentration remained low (PO_4-P, 0.10 ppm; NO_3-N, 0.25 ppm). None of the ponds visited had a dense plankton bloom (Secchi disk visibility $\geq$ 60 cm), hence nutrient availability should increase (liming, fertilization).

Availability of inputs for aquaculture

No lime was available in the study area. However, the Niger State Agriculture Development Programme, sponsored by World Bank, will order and distribute lime as soon as farmers ask for it. The only organic fertilizer found in reasonable large quantities was chicken manure. Inorganic fertilizers were available at subsidized rates (80%) throughout the study area. As inorganic fertilizers are extremely cheap, commonly available and easy to transport and store, farmers with limited transport capability, could depend primarily on inorganic fertilizers.

Commercial fish feeds were available, but the supply was irregular and the price too high considering selling prices of fish. Small farmers could produce their own supplementary feeds, using broken maize, millet, sorghum or soya beans. When used in moderate quantities the feed conversion will be low and fish production will increase considerably. However, these ingredients are not always cheap, and competition with human consumption is faced. The best fish farming approach therefore will be to maximize natural production and to minimize artificial feeding.

SOCIO-ECONOMICS OF FISH FARMING AT VILLAGE LEVEL

The people

The people inhabiting the Bida area are known as Nupe. In the villages the state is represented by the village head, who collects taxes, organizes elections, etc. However, traditional power belongs to the local chief, who is elected from a noble Nupe family for life. The duties of the local chiefs are threefold: religious leadership (islam), settle land and water use disputes, and guard the history of the village. Especially in rural communities, villagers (inclusive the village head), will not take any initiative without the consent of the local chief.

Table 4. Costs and returns of fish culture in small (0.02-ha) and large (10-ha) ponds with high and low level of production intensity. Source: Hekstra et al. 1988.

POND SIZE:	0.02-ha	0.02-ha	10.0-ha	10.0-ha
INPUT LEVEL:	low	high	low	high
total annual fixed costs	978.9	978.9	50,890.5	50,890.5
Total annual operational costs	249.6	1,618.5	92,455.2	498,779.2
TOTAL ANNUAL COSTS	1,228.5	2,597.4	143,345.7	549,669.7
Fish sales in Bida				
TOTAL ANNUAL RETURN (fish sales)	325.-	1,200.-	97,500.-	320,000.-
TOTAL ANNUAL BENEFIT/LOSS	903.5 loss	1,397.4 loss	45,845.7 loss	229,669.7 loss
Fish sales in large city in south				
TOTAL ANNUAL RETURN			195,000.-	640,000.-
TOTAL ANNUAL BENEFIT/LOSS			51,654.3 benefit	90,330.3 benefit

The farming systems

Land labour is exclusively a male occupation, women take charge of processing and marketing. Men mostly organize on-farm work, although occasionally, women can operate as agricultural entrepreneurs, buying and hiring all the inputs, inclusive labour.

Farmers commonly use low quantities of inorganic fertilizer. A form of shifting cultivation is practiced on upland soils. Crops planted are: guinea corn, sorghum, melons, groundnut, maize, yam, cow pea, cassava, okra and sweet potato. In the lowland, rice is the major crop. Nearly all production is consumed within the family, with the exception of rice, which is sold for cash. In addition, considerable amounts of maize are bought.

During the planting season, there is a labour shortage. Most farmers hire laborers, on average up to 40% of the total labour input. Farmers always first plant their upland crops. Rice is planted relatively late, and water shortage towards the end of the growing season is common.

Fishing rights

Fishing is done throughout the year, but the peak activity is at the end of the dry season, when the water level in the lakes is low, and when on farm labour demand is minimal. As a rule, fishermen combine fishing with farming.

Anyone has the right to fish in the rivers. In contrast, the fishing rights in natural lakes and ox-bows along the Niger and Kaduna rivers are owned by the important families in the nearest village. The family head decides which fishermen are allowed to fish, and under which terms. Different agreements are possible, the common agreement being that the owner of the fishing rights receives one third of the catch, or the biggest fish caught that day. Sometimes, the fishermen buys in advance the right to fish a water body for a fixed period of time. Both the owner of the fishing rights and the fishermen, respect and obey the agreement. The advantage of the existence of fishing rights is that fishing regulations can be put forward and will be obeyed.

Table 5. Alternative fish farming systems. Culture based fisheries in ox-bows and extensive fish culture in dam reservoirs. Source: Hekstra et al. 1988.

	culture based fisheries	extensive aquac. in dam reservoirs
SURFACE	10.0-ha	4.0-ha
PROD. HA	400 kg	2,285 kg
total annual fixed costs	2,181.-	10,275.6
total annual oper. cost	10,330.-	26,403.7
TOTAL ANNUAL COSTS	12,511.-	36,679.3
TOTAL ANNUAL RETURN (fish sales)	16,600.-	48,800.-
TOTAL ANNUAL BENEFIT	4,089.-	12,120.7
ANN. RETURN ON INVESTM. (%)	32.7	33.0

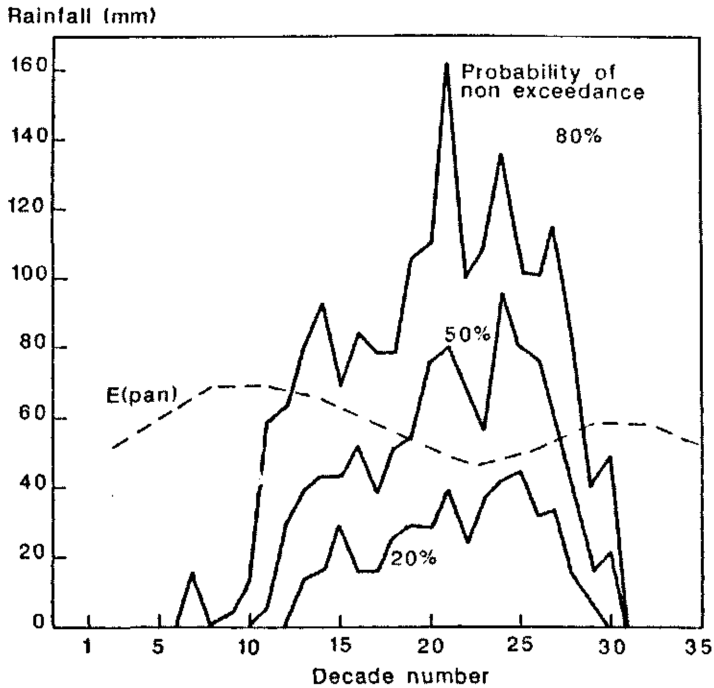

Figure 3. Yearly rainfall and evaporation pattern for Bida (based on measurements during 20 years). 1 decade = 10 days. Source: Palada et al. 1987.

Feasibility of aquaculture

Results of the cost-benefit analysis of fish culture in ponds are given in Table 4. It follows that both small-scale (0.02-ha) and large-scale (10-ha) fish farming are not economically viable if fish are sold in the study area, irrespective of the level of production intensity. Large-scale fish farming can be feasible, provided the fish is sold in large towns like Lagos, in which case extensive fish farming is economically more attractive than intensive (Table 4). Two major reasons can be given for this discouraging results:

- Pond construction is expensive, leading to high fixed costs.
- Water availability in the study area is restricted, allowing only a short (8 month) production cycle.

Under the given circumstances it is worthwhile to consider the possibility to create a water body at minimal costs, preferentially, holding water the whole year, to be used for extensive aquaculture. Possible sites in the study area are the natural ponds (ox-bows) in the river floodplains and the existing small dam reservoirs in stream flow valleys.

The ox-bows in the floodplains do not allow for a fish farming management per se, because drainage, and a complete qualitative and quantitative control of the fish stock, are impossible. However, these ox-bows allow for a culture based fisheries management (put-grow-take fishery) as a transition from capture fisheries to fish farming.

Small dam reservoirs in stream flow valleys which can be drained completely, allows for a complete control of the fish stock. In addition, different managerial measurements to eventually intensify the production process, for instance by manuring/fertilization and/or supplementary feeding become possible.

Farmers in the study area practice extensive agriculture, reducing inputs to a bare minimum. As such, they will not take up aquaculture techniques that require high input levels, since such a system runs against their general attitude towards agricultural production. In consequence, only the introduction of extensive aquaculture practices should be considered.

Tentative production scenarios have been analyzed for exploitation of ox-bows and dam reservoirs, both with low intensity management (Table 5). The two scenarios proved feasible under the local circumstances (annual return on investment 33 %).

CONCLUSIONS AND RECOMMENDATIONS

Commercial fish farming in artificially constructed ponds at village level was not feasible. Large scale industrial aquaculture, using large production surfaces in an intensive way, are in principle profitable provided such enterprises are located on impermeable soils close to big population centers and avail over a safe and dependable fish seed supply as well as over experienced staff.

Capture fisheries - which is a widely practiced dry season activity in the rural areas of the sub-humid wetlands, is the major source of fish and fish products. Fish supply from capture fisheries is limited by the production potential of the ecosystem (nutrient availability, solar radiation) and at present is decreasing relative to the social demand (habitat modifications, population growth).

Taking into account the above mentioned points, an increase in fish production is these rural areas can only be brought into effect by artificially increasing the yield of the natural ecosystem and by introduction of aquaculture in these locations where the socio-economical constraints mentioned are absent or not prohibitive. Such an approach should aim at those natural ecosystems which in view of their size and site are manageable and at those locations where the costs of pond construction are low relative to the water surface created. Possible solutions are to use ox-bows in the floodplains and to construct small dam reservoirs in stream flow valleys.

Ox-bows

On average, the ox-bows yield roughly 50-150 kg per ha per annum, which can be regarded as the present maximum yield in view of resident stock, nutrient content, and solar radiation, the first and the second parameter being susceptible to man-made control. Manipulation of the resident fish stock by taking out what is undesired and putting in what is desired offers a possibility to direct the energy and material flow in the system more efficiently towards fish production. Artificial enrichment by manuring/fertilizing and supplementary feeding can be regarded as - be it new - variations on the present 'inputs', the introduction of which is facilitated by the existence of fishing rights as is stressed in this document.
In short, such a seasonal put-grow-take fishery is thought to be 'socially absorbable' as well as feasible in the rural areas of the African wetlands. In addition, considering the numerous ox-bows found throughout West Africa such an approach is also highly multipliable in the region.

Small-dam reservoirs

In stream flow valleys, small dams can be constructed creating - relatively to the length of the dam - large water surfaces. These reservoirs can be used for all different managerial types of seasonal extensive up to intensive pond farming, provided dam construction allows for draining. If drainage is impossible, dam reservoirs should be managed similarly to ox-bows.

Pond farming in dam reservoirs is a logical follow-up in the developmental sequence of aquatic resource management, which goes from capture fisheries via culture based fisheries to (different types of) pond farming and may continue to other types of environmentally controlled aquaculture husbandry and farming systems.

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