Proceedings of the 4th Biennial Conference
of the
African Farm Management Association

# Farm and Farmer Organisation for Sustainable Agriculture in Africa



Edited by
Johann Laubscher

26 - 30 January 1998
University of Stellenbosch, South Africa

# SUSTAINABLE USE OF EXISTING IRRIGATION WATER BODIES BY MEANS OF AQUACULTURE IN SOUTH AFRICA: A CASE STUDY

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## ABSTRACT

*There are numerous water bodies in South Africa that have the potential to be utilised for aquaculture practices without an additional load being placed on water consumption. For example, the Western Cape has over 2 000 irrigation dams each with a water volume in excess of 500 000 $m^3$ which are suitable for aquacultural activities and have the potential to produce an estimated 5 800t of freshwater fish per annum. The question that arises is whether the fish enrich or pollute the water relative to the primary function of that water, e.g. irrigation of high value crops such as table grapes and deciduous fruits destined for export. One of the major chemical compounds derived from an aquaculture industry causes an increase in the nitrogen content of the water, which is caused by both excess feed decomposition and fish metabolism. An intensive investigation of an integrated agriculture-aquaculture project in the Western Cape showed no negative impact of the aquaculture activity on the water quality in terms of nitrogen, pH, turbidity, conductivity or total dissolved and suspended solids content. The aquaculture project delivered 4 500 kg of trout over a seven month growth period in a cage system which realised a return of 17.2% on the investment.*

## 1. Introduction

In terms of integrated agriculture-aquaculture, sustainability of the aquaculture operation refers to a viable aquaculture activity without any long-term negative effect on the water quality and the production quality of the integrated agricultural activity. The target range for the nitrogen content of water used in irrigation is 0-5 mg/litre, so that during irrigation most of the nitrogen would be utilised by the irrigated crop and a minimum would be leached to the ground water. In an integrated agriculture-aquaculture system, the objective of the fish farming activity is therefore to keep the nitrogen levels in the water within this range, bearing in mind that ammonia and nitrites, but not nitrates, are highly toxic to fish. The farmer could also save on nitrogen fertilisers if the water from the production dam is used for crop irrigation.

The Western Cape has over 2000 irrigation dams with a volume in excess of 500 000$m^3$ which have an estimated production potential of 5800t of freshwater fish. Fish species suitable for aquaculture in the Western Cape are trout (*Oncorhynchus mykiss*), tilapia (*Oreochromis mossambicus*) and carp (*Cyprinus carpio*). These fish species provide the local market with high value fish products and stimulate further product development for niche and conventional markets. The aquaculture enterprise can also provide the emerging small-scale farmer with an additional income which will further his development towards total financial independence.

## 2. Materials and methods

The irrigation dam being investigated was sited at Nietvoorbij, an experimental farm for viticulture and oenology, in the Stellenbosch District (33 55' 00" S 18 51' 50" E). The dam has a surface area of ±5 hectares with a mean depth of 10m and a volume of 500 000$m^3$. The annual flow-through is 1.5 times the volume of the dam. The vineyards are irrigated from this dam at the onset of the warmer months, which is in the region of October.

The fish were reared in a system consisting of two floating cages (10 X 10 X 5m depth) stocked with 2300 fish per cage which is 4.6 fish/$m^3$. Fingerlings were stocked at an initial weight of 250g and harvested seven months later at a mean weight of 1.1 kg. The project is owned and managed by a resident technician at Nietvoorbij who manages the system during free times and over weekends. On average, he has spent 3 hours per day, about 1 hour at a time, feeding and monitoring the fish. Every month of the trout production cycle, 3 hours were needed for weighing fish (10% of total) and calculating the average weight. The fish population was graded in August into two uniform weight classes. An extension officer visited the site every second week to monitor the production and collected water samples for analysing and, when necessary, gave advice. The project was financed through a R50 000 loan (10% interest per annum) as starting capital payable over a five-year period.

Water samples from three different locations on the cages were taken fortnightly from the period prior to stocking until harvesting. The water sampling was done at a depth of 2m. The water samples were then analysed by the accredited laboratory of the Division of Water, Environment and Forestry Technology of the CSIR for the following parameters: pH, Nitrate/Nitrite (mg/l), Ammonia (mg/l), Conductivity (mS/m), Total Suspended Solids (TSS) (mg/l) and Total Dissolved Solids (TDS) (mg/l). The water oxygen content and temperature were measured in the same sampling spots.

With the exception of the final fish count, all fish numbers were calculated from the initial stocking mass divided by the mass of an individual fish, calculated from a sub-sample of the population. The monthly-calculated average weight was used to determine their growth and adjustment to the feeding programme made accordingly. The fish were fed a standard commercial trout pellet diet (38% protein). Reports were filed on mortality and monthly expenditures.

## 3. Results

The fortnightly water analyses of the parameters that may be influenced by the aquaculture activity are summarised in Table 1.

**Table 1. The water quality (fortnightly sampling) adjacent to the cages**

| Date | Ammonia Nitrogen | Nitrate & Nitrite | Cond | pH | TDS | TSS | Temp (mean) | Oxygen (mean) | |
|---|---|---|---|---|---|---|---|---|---|
| | mg/l | mg/l | mS/m | | mg/l | mg/l | C° | mg/l | % |
| 06-05-97 | 0.21 | 0.10 | 43 | 7.6 | 275 | 3.0 | | | |
| 20-05-97 | 0.22 | <0.1 | 43 | 7.1 | 275 | 7.0 | | | |
| 03-06-97 | 0.10 | <0.1 | 43 | 7.3 | 275 | 3.2 | | | |
| 18-06-97 | 0.13 | <0.1 | 43 | 7.5 | 275 | 5.0 | | | |
| 14-07-97 | <0.1 | <0.1 | 41 | 7.6 | 262 | 5.6 | 12.3 | 7.5 | 73.3 |
| 30-07-97 | <0.1 | 0.13 | 42 | 7.3 | 269 | 5.0 | 12.2 | 8.6 | 87.3 |
| 12-08-97 | <0.1 | 0.20 | 42 | 7.5 | 269 | 7.0 | 12.5 | 9.6 | 93.3 |
| 25-08-97 | <0.1 | 0.15 | 40 | 8.3 | 256 | 7.1 | | | |
| 09-09-97 | 0.12 | <0.1 | 40.5 | 7.5 | 259 | 7.2 | 14.0 | 7.6 | 76.3 |
| 23-9-97 | <0.1 | <0.1 | 40.8 | 7.9 | 261 | 10.5 | 17.6 | 9.5 | 103 |
| 08-10-97 | <0.1 | <0.1 | 41 | 8.2 | 262 | 4 | 18.2 | 8.4 | 90.3 |
| 21-10-97 | <0.1 | <0.1 | 39 | 9.1 | 250 | 5 | 21.3 | 10.2 | 120.3 |

Values indicated as < 0.1 mg/l are below the minimum detection limit of 0.1 mg/l. Initially, there was a build-up of ammonia, which then dropped below 0.1m g/l after eight weeks. The other nitrogen compounds (nitrite and nitrate) showed no fixed trends in their concentration. The rainfall and water evapotranspiration for the fish growth period are summarised in Table 2.

**Table 2: The rainfall and evapotranspiration from March till October 1997**

| Month | Rainfall mm | Evapotranspiration mm/d |
|---|---|---|
| March | 5 | 5.8 |
| April | 60 | 3.5 |
| May | 82 | 2.3 |
| June | 155 | 1.9 |
| July | 30 | 2.1 |
| August | 91 | 3.0 |
| September | 14 | 4.2 |
| October | 18 | 6.5 |

A typical winter rainfall was noted, i.e. a gradual increase in rainfall accumulating in a peak in June (155 mm) before starting to decline in September. Similarly during this period, the evapotranspiration showed an inverse relationship, decreasing during the rainfall peak with a minimum of 1.9 mm/d during June. Of special note is the low rainfall noted in July (30 mm), a period where high rainfall is normally experienced in the Western Cape rainfall region.

The amount of feed used for the period was 5 500 kg with an average feed conversion ration of 1.6:1. The monthly fish growth rate and mortality are summarised in Table 3.

**Table 3: The monthly survival and mean weight of the fish during the seven-month growth period.**

| Date | number of fish | | | average weight of fish (g) | |
|---|---|---|---|---|---|
| | cage 1 | cage 2 | total | cage 1 | cage 2 |
| 20/5/97 | 2295 | 2427 | 4722 | 257 | 257 |
| 23/6/97 | 2293 | 2426 | 4719 | 495 | 467 |
| 21/7/97 | 2293 | 2425 | 4718 | 633 | 615 |
| 24/8/97 (grading) | 2346 | 2251 | 4597 | 852 | 720 |
| 23/9/97 | 2346 | 2251 | 4597 | 966 | 824 |
| 27/10/97 | 2340 | 2245 | 4585 | 1100 | 986 |

The initial stocking size of the fish (257g) is higher than normal (180-200g), caused by a delayed introduction due to the late completion of the cage structures. The realised mortality was 1.2%.

The basic financial outlay of the aquaculture enterprise is summarised in Table 4.

**Table 4: The cash-flow report for the 1997 season**

| | |
|---|---|
| **Running Costs** | |
| Fingerlings | R 17 600 |
| Feed | R 20 360 |
| Labour | R 1 200 |
| Loan repayment (R50 000 @ 10% over 5 yrs) | R 12 672 |
| **Total** | **R 51 832** |
| **Income** | |
| Fish sales (4500 kg @R13.50/kg) | R 60 750 |
| **Gross Profit (R)** | **R 8 918** |
| Gross Profit (%) | 17.2 |

The labour cost depicted in Table 4 was supplemental labour. The loan repayment is calculated on the basis of a R50 000 loan at an annual interest rate of 10%, payable over a 5-year period. All the fish were harvested and sold to a local processor. Future running costs and income are expected to show inflationary increases.

## 4. Discussion

Although the ammonia concentration showed an initial increase, a decreasing trend in concentration was noted (Table 1) which can be ascribed to the diluting effect of the winter rainfall (Table 2). *Nitrosomonas* and *Nitrobacter* bacteria in the substrate of the pond could also have been responsible for the conversion of ammonia into nitrites and nitrates. These bacterial species normally take eight weeks to initialise and stabilise (Boyd 1982). Nitrite and nitrate concentrations showed a fluctuation during this period but no up or downward trends could be detected. It was, however, expected that there would be an increase in the concentration of these two compounds. The diluting effect of the rain and possible utilisation of the nitrogen compounds by phytoplankton may have caused this lack of increase. During this time the critical limits for fish health (nitrate 300 mg/l, nitrite 0.05 mg/l) and irrigation (nitrogen 5 mg/l) (Department of Water Affairs and Forestry 1996 a, b) were not exceeded. As the water nitrogen content was below 0.1 mg/l, there would not be any fertiliser saving-effect on the farming enterprise. In a cage production system utilising African catfish (*Clarias gariepinus*) in an irrigation dam in Mpumalanga, a net fertiliser saving of 9% per annum was realised when using the enriched water for the production of 55 ha lucerne. If the water body in this system was developed to carry its full load of fish, a net fertiliser saving per annum of 62% is projected (Viljoen, 1996). The low water nitrogen value measured in the present investigation would also seem to indicate that this specific water body could maintain a much higher fish stocking density.

Conductivity and total dissolved solids showed an identical downward trend. This is also a result of the seasonal water inflow (Table 2). The conductivity did not exceed the target water quality range for irrigation (40 mS/m) (Department of Water Affairs and Forestry, 1996a). The pH fluctuated between 7.1 - 9.1, values which had no negative effect on the fish or water quality (Department of Water Affairs and Forestry, 1996b.). The total suspended solids (TSS) showed a slight increase of 5 mg/l mainly due to turbidity caused by inflowing rainwater as well as suspended algae growth during the latter part of the season. The water temperature showed a natural seasonal increase and the increase in oxygen concentration is most probably due to the presence of the algae.

The fish showed growth similar to that experienced in other cage culture systems in the region. A total production of 4500 kg was achieved with a low mortality of 1.2% over the whole growth period.

The financial statement for 1997 showed a gross profit of R8 918 (17.2%). The expectation was to achieve a higher gross profit (21.1%) in the following year with the earlier introduction of smaller fingerlings resulting in related savings of production costs. It was expected to maintain this level of profit over the next four years, after which the loan repayment would be completed. Thereafter gross profit was expected to increase to a level of 46%. The life span of all capital assets (cage structures, nets and equipment) was estimated to be 10-12 years. Through utilisation of the existing farm infrastructure (i.e. roads, dam, workshop etc.) a substantial amount of capital costs were saved in comparison with other agriculture ventures.

Fish farming can therefore be successfully implemented on irrigation dams and should receive consideration for application on other irrigation systems. The on-going research on reducing production costs and the application of alternative species in summer (e.g. tilapia, carp) will enhance the future economic viability of such integrated agriculture-aquaculture systems. The importance of an on-going water quality-monitoring programme must be stressed, to ensure protection of the irrigation of crops. Secondary benefits, such as improved expendable income, development and transfer of entrepreneurial skills to the emerging farmers, have made an important socio-economic contribution to the participating communities.

## 6. Acknowledgement

Ministry of the Flemish Community, Science Policy Programming Administration for financial assistance.

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