Rice–Fish Culture in China

Edited by Kenneth T. MacKay

International Development Research Centre

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/U/mixed farming/ , /cultivation systems/ , /China/ — /appropriate technology/ , /ecology/ , /economic aspects/ , /on-farm research/ , /case studies/ , /conference reports/ , references.


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Ecology and Economics of Rice–Fish Culture

Quing Daozhu and Gao Jusheng

The hilly district in the south of Hunan Province is one of the birthplaces of fish-rearing in mountain ponds and in ricefields. The area devoted to rice–fish culture was 30,000 ha in 1987. In Qiyan County alone there were 10,000 ha. Rice yields range from 7,500 to 13,500 kg/ha, yields of fresh fish from 450 to 750 kg/ha, and output values from CNY6,000 to CNY10,500/ha. The economic and ecological effects of rice–fish culture are remarkable. Research on high-yield technology systems and the ecological and economic effects of rice–fish culture has been conducted since 1985.

Materials and Methods

Grass carp, silver carp, common carp, variegated carp, and crucian carp were tested. Summer fingerlings (3–5 cm long) were reared in the rice nursery of late rice for 20–30 days. They were stocked in the ricefields at the end of May or the beginning of June. Different rice varieties were grown each year: early rice (Zhuxi 26) and late rice (V64) in 1985, early rice (Zhuxi 26) and late rice (79-16, a strain with disease resistance) in 1986, and early rice (V49) and late rice (V64) in 1987. The size of the transplanted rice varied according to rice cultivars. The other planting conditions were: hill spacing 13 cm x 20 cm, 7–8 seedlings per hill, and 375,000 hills/ha for common rice, and hill spacing 17 cm x 20 cm, 2–4 seedlings per hill (including tiller), and 300,000 hills/ha for hybrid rice.

The experiments were conducted in a gleyed ricefield in Guangshanping Village in Qiyan County and in a ricefield with a green manure crop on the farm of the Hangyan Red Loam Experimental Station. The experiment included four treatments (no replications): ridge culture with tillage (RCT) in the gleyed ricefield (control, 0.03 ha), ridge culture with no tillage (RCNT) in the gleyed ricefield (0.03 ha), fish-rearing and ridge culture with no tillage (FRCNT) in the gleyed ricefield (0.12 ha), winter crop or green manure crop plus fish and early rice with ridge culture and tillage plus fish and late rice with no tillage (W-FRT-FRNT) (0.11 ha).

About 7–10 days before the rice seedlings were transplanted, 1.2-m wide ridges were made. The furrows were 30 cm wide and 20 cm deep (the main ridge furrow was 40 cm wide and 30 cm deep). The fish pit was 3 m x 3 m. Decomposed pig and cow manure (1,500 kg) was applied to the surface of soil before ridging. Urea

70 Hengyan Red Loam Experimental Station, Chinese Academy of Agricultural Sciences, Hengyan, Hunan Province.
Table 1. The number of weeds per square metre with two rice–fish culture methods using early rice cultivar Weiyou 49 (1987).

<table>
<thead>
<tr>
<th>Species of Weed&lt;sup&gt;a&lt;/sup&gt;</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCNT&lt;sup&gt;b&lt;/sup&gt;</td>
<td>22.0</td>
<td>3.5</td>
<td>0.3</td>
<td>—</td>
<td>few</td>
<td>few</td>
<td>many</td>
</tr>
<tr>
<td>FRCNT</td>
<td>5.0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<sup>a</sup> Weeds: 1 Monochoria vaginalis, 2 Echinochloa crusgalli, 3 Scripus maritimus, 4 Ammannia baccifera, 5 Eleocharis acicularis, 6 Potamogeton franchetii, and 7 Azolla pinnata.

<sup>b</sup> RCNT ridge culture with no tillage, FRCNT fish-rearing and ridge culture with no tillage.

(150 kg/ha), calcium superphosphate (450 kg/ha), and potassium chloride (150 kg/ha) were applied on the surface of the ridge before the rice seedlings were transplanted. In addition, 112.5 kg/ha of urea were broadcast.

**Analysis of Experimental Results**

**Effect on Rice Growth**

Rice–fish culture is a high-yield technology that makes good use of available resources and provides ecological benefits. To compare the effects on rice growth of different methods of planting and rearing, observations were made on the dynamics of rice tillering. There were no great difference in the number of rice stems (including tillers) in the early stage among RCT, RCNT, and FRCNT. The differences increased in the middle–late stage. The numbers of rice stems (including tillers) in the peak tillering stage were: 8 million/ha in the field with RCT, 6 million/ha with RCNT, and 5 million/ha with FRCNT. However, the difference in effective panicles became smaller at maturity. In the ACT field, the rice grew quickly and there were more tillers, but there were also more ineffective tillers and the percentage of ear-bearing tillers was low. In this field, there were 5.5 million ear-bearing tillers per hectare and the rate of ear bearing was 69.2%, with RCNT there were 4.7 million ear-bearing tillers per hectare and the rate of ear bearing was 78.1%, and with FRCNT there were 4.1 million ear-bearing tillers per hectare and the rate of ear bearing was 81.2%. The number of ineffective tillers was lower but the rate of ear bearing was higher in the rice–fish fields because the small tillers at the base of the rice plant were eaten by the fish.

**Weeds, Diseases, and Pests**

During the vegetative cycle of the rice, there were almost no weeds with rice–fish culture because the weeds became the natural food of the fish. There were 15 species of weeds in ricefields with RCT and RCNT. Monochoria vaginalis (21.8 and 22.0 plants/m<sup>2</sup>) and barnyard grass (Echinochloa crusgalli) (4.0 and 3.5 plants/m<sup>2</sup>) were the most common weeds (Table 1).
Table 2. Relationship between the incidence of rice diseases and insect pests and rice–fish culture in fields of the early rice cultivar Weiyou 49 (1987)*.

<table>
<thead>
<tr>
<th></th>
<th>Rice Sheath Blight Disease (%)</th>
<th>Rice Leafroller (No./100 hills)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCT</td>
<td>2.1</td>
<td>5.71</td>
</tr>
<tr>
<td>RCNT</td>
<td>3.9</td>
<td>4.25</td>
</tr>
<tr>
<td>FRCNT</td>
<td>6.3</td>
<td>4.08</td>
</tr>
</tbody>
</table>

* Data were obtained during the rice booting stage (21 June). RCT ridge culture with tillage, RCNT ridge culture with no tillage, FRCNT fish-rearing and ridge culture with no tillage.

Table 3. The influence of different forms of rice–fish culture on the economic properties and yield of the early rice cultivar Weiyou 46 (1987).

<table>
<thead>
<tr>
<th></th>
<th>RCT*</th>
<th>RCNT</th>
<th>FRCNT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective panicles (1 000/ha)</td>
<td>372</td>
<td>322</td>
<td>292</td>
</tr>
<tr>
<td>Grains (no./panicle)</td>
<td>103.5</td>
<td>106.4</td>
<td>137.2</td>
</tr>
<tr>
<td>Setting percentage</td>
<td>71.6</td>
<td>72.4</td>
<td>64</td>
</tr>
<tr>
<td>Weight of 1 000 grains (g)</td>
<td>26.8</td>
<td>26.5</td>
<td>27</td>
</tr>
<tr>
<td>Yield (kg/ha)</td>
<td>8 194</td>
<td>8 058</td>
<td>7 454</td>
</tr>
</tbody>
</table>

* RCT ridge culture with tillage, RCNT ridge culture with no tillage, FRCNT fish-rearing and ridge culture with no tillage.

Table 4. Economic benefits of fish–culture and rice ridge culture.

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual Rice Yield (kg/ha)</th>
<th>Rice Value* (CNY/ha)</th>
<th>Fish Income (CNY/ha)</th>
<th>Annual Total Income (CNY/ha)</th>
<th>Percentage Total Income from Fish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field with winter crop or green manure</td>
<td>1985 9 774</td>
<td>3909</td>
<td>813</td>
<td>4723</td>
<td>17.2</td>
</tr>
<tr>
<td></td>
<td>1987 11 282</td>
<td>4513</td>
<td>2650</td>
<td>7159</td>
<td>37.0</td>
</tr>
<tr>
<td>Gleyed ricefield</td>
<td>1985 12869</td>
<td>5147</td>
<td>2258</td>
<td>7405</td>
<td>30.5</td>
</tr>
<tr>
<td>Field (winter)</td>
<td>1986 11162</td>
<td>4465</td>
<td>1664</td>
<td>6 129</td>
<td>27.2</td>
</tr>
<tr>
<td>Winter-water field</td>
<td>1987 13124</td>
<td>5249</td>
<td>3611</td>
<td>8860</td>
<td>40.8</td>
</tr>
</tbody>
</table>

* Price of rice CNY40/100 kg; fish at market price each year.
The results were different for insect pests and rice diseases. The incidence of rice sheath blight disease was 6.3% in the rice–fish fields compared with 3.9% and 2.1% in the field with RCNT and RCT, respectively. The number of rice leafrollers in the rice–fish fields was 4.1 heads per 100 hills compared with 5.7 and 4.3, respectively, in the fields with RCT and RCNT (Table 2).

Fish rearing reduced the amount of pesticides and the frequency of spraying. As a result, beneficial organisms were increased. For example, there were 380 000 red mites per hectare in the rice–fish fields compared with 65 500–86 000 in ricefields without fish. There were also nearly twice as many frogs.

**Soil Fertility**

Ridges help raise the soil temperature of the cultivated layer, which promotes the conversion of potential nutrients. Fish in the ricefields fertilize the soil with their excrement. Analysis of soil samples taken from the cultivated layer after rice and fish were harvested indicated that organic matter content was 4.11%, total nitrogen 0.21%, total phosphorous 0.09%, alkali-hydrolyzable nitrogen 152.72 ppm, and content of available phosphorus 9.85 ppm. The same measures of soil samples from fields without fish were slightly less: 4.0%, 0.2%, 0.08%, 127 ppm, and 4.5 ppm, respectively. Soil nutrients were higher in rice–fish fields than in rice-only fields.

**Rice Yield**

Fish culture lowered rice yields. The number of effective panicles was highest in the field with RCT and lowest with FRCNT. Rice yields were 8 195 kg/ha with RCT, 8 058 kg/ha with RCNT, and 7 454 kg/ha with FRCNT (Table 3).

An analysis of 13 samples taken between 1984 and 1986 showed that the difference in rice yield between RCT and RCNT was not significant. The rice yield from ridge culture was not significantly different between RCT and RCNT, but both were higher than the yield from the rice–fish field. However, in the gleyed field, zero tillage not only saved labour, but shifted the time of transplanting to earlier in the season. The adoption of no tillage also greatly reduces mechanical damage to fish and enhance their survival. This promotes higher yields of both rice and fish and increases the total value of the output.

**Economic Benefits**

When developing a plan for field engineering and cultivation technologies, the basic principle is that rice is the main crop and fish is the secondary one. The establishment of a good ecosystem makes full use of space, land, and water in the ricefield and to greatly raises the biomass and total value of the output of the ricefield with little extra more input or cost.

From 1985 to 1987, the experiment on fish-farming and ridge culture of rice with no tillage produced 9 774–13 124 kg/ha of rice (both early and late rice). The value
Table 5. Cost and survival rates of fish reared in 0.6 ha of ricefields (1985–1987).

<table>
<thead>
<tr>
<th>Species</th>
<th>No. of Fish Stocked</th>
<th>No. of Fish Harvested</th>
<th>Survival Rate (%)</th>
<th>Cost of Fish (CNY)</th>
<th>Income from Fish (CNY)</th>
<th>Net Income (CNY)</th>
<th>Percentage of Each Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass carp</td>
<td>16000</td>
<td>4928</td>
<td>30.8</td>
<td>49.0</td>
<td>854.2</td>
<td>805.2</td>
<td>65.5</td>
</tr>
<tr>
<td>Silver carp</td>
<td>2460</td>
<td>522</td>
<td>21.2</td>
<td>10.7</td>
<td>157.6</td>
<td>146.9</td>
<td>12.0</td>
</tr>
<tr>
<td>Common carp</td>
<td>2650</td>
<td>1025</td>
<td>38.7</td>
<td>24.6</td>
<td>150.4</td>
<td>125.8</td>
<td>10.2</td>
</tr>
<tr>
<td>Crucian carp</td>
<td>300</td>
<td>160</td>
<td>53.3</td>
<td>3.5</td>
<td>31.6</td>
<td>28.1</td>
<td>2.3</td>
</tr>
<tr>
<td>Other</td>
<td>42500</td>
<td>6920</td>
<td>16.3</td>
<td>26.9</td>
<td>149.5</td>
<td>122.6</td>
<td>10.0</td>
</tr>
<tr>
<td>Average/ha</td>
<td>114120</td>
<td>24210</td>
<td>21.2</td>
<td>204.9</td>
<td>2398.5</td>
<td>2193.8</td>
<td>—</td>
</tr>
</tbody>
</table>

Table 6. Economic effects of rice–fish culture.

<table>
<thead>
<tr>
<th>Cultivating Method*</th>
<th>Early Rice</th>
<th>Late Rice</th>
<th>Winter</th>
<th>Rice Yield (kg/ha)</th>
<th>Value of Rice Income (CNY/ha)</th>
<th>Fish Income (CNY/ha)</th>
<th>Increased Income (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gleyed field (control)</td>
<td>T</td>
<td>T</td>
<td>WWF</td>
<td>12192</td>
<td>4877</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>1987</td>
<td>ZT</td>
<td>ZT</td>
<td>11637</td>
<td>4655</td>
<td>—</td>
<td>-4.8</td>
</tr>
<tr>
<td>Green manure or winter crop</td>
<td>T</td>
<td>ZT</td>
<td>GM</td>
<td>9774</td>
<td>3909</td>
<td>813</td>
<td>-3.3</td>
</tr>
<tr>
<td></td>
<td>1987</td>
<td>ZT</td>
<td>ZT</td>
<td>11282</td>
<td>4513</td>
<td>2647</td>
<td>31.9</td>
</tr>
<tr>
<td></td>
<td>ZT</td>
<td>ZT</td>
<td>Barley</td>
<td>12519</td>
<td>5008</td>
<td>2258</td>
<td>32.9</td>
</tr>
<tr>
<td></td>
<td>1986</td>
<td>ZT</td>
<td>ZT</td>
<td>11162</td>
<td>4465</td>
<td>1664</td>
<td>20.4</td>
</tr>
<tr>
<td></td>
<td>1987</td>
<td>ZT</td>
<td>ZT</td>
<td>13124</td>
<td>5249</td>
<td>3769</td>
<td>45.9</td>
</tr>
</tbody>
</table>

* T tillage, ZT zero tillage, WWF winter-water fields, GM green manure.

of the rice was CNY3 909–5 349/ha and the value of the fish was CNY813–3 610/ha. Total income increased by 17–41%, a significant economic benefit. Among different types of ricefields, rice yields and fish income differed greatly. In the fields of winter rice or winter green manure, water deficits during growth of late rice affected both rice and fish. As a result, rice yields were only 9 774–11 282 kg/ha, which was 12–14% lower than from the winter-water fields.
The income derived from fish in the winter-rice or green-manure field was CNY813-2,650/ha and the fish income in the gleyed ricefield was CNY2,258/ha (Table 4).

The best choices for rice–fish fields are winter-water gleyed fields that have plenty of water, but are easy to drain. Under these conditions, good growth of both fish and rice are ensured.

Polyculture

There are many types of rice–fish farming. Most farmers still use the traditional method of a level field to rear small-size common carp fry in natural water. As a result, fish output is low, commonly 150–300 kg/ha from one-season ricefields. Because the price of common carp is only CNY2–3/kg, fish income is also low. Some farmers also maintain 3–4 cm of water in the field for a long time for the sake of fish. This affects the growth and development of the rice and leads to a reduction of rice yields and only slightly higher income from the fish.

A complete set of technological measures were applied in these experiments: the rice was planted on ridges, early rice (middle–late maturing variety) was selected, plant spacing was reduced, and tillage was increased in late ricefields. Problems of long-term submergence of the ricefield after the fish were reared were avoided. Moreover, polyculture of 3–5 varieties of fish raised the survival rate and increased the income generated from the fish (Table 5).

With polyculture, the value of grass carp contributed 65.5% of total fish income. The survival rates for the different species were: variegated carp 53.3%, common carp 38.7%, silver carp 21.2%, and other fish (e.g., crucian carp) 16.3%. From 1985 to 1987, the experimental area for fish farming in ricefields was 0.56 ha and the average income from fish was CNY2,194/ha.

The main ecological models for rice–fish culture in ricefields are rice–fish–duckweed and rice–fish. Rice–fish with ridge culture and no tillage was compared with RCT and RCNT. For the rice–fish system, two types of fields (winter ricefields and winter-water gleyed ricefields) were used (Table 6). The field with RCT had an output value of CNY4,876/ha, which was 4.8% higher than with no tillage. In the green-manure crop or winter-crop field with rice–fish, the output value was 31.9% higher than with RCT. In the gleyed field with FRCNT, there was an increase of 20–46% compared with RCT. There are clear the economic benefits to fish-rearing and ridge culture of rice with no tillage.