Rice–Fish Culture in China

Edited by Kenneth T. MacKay

International Development Research Centre
Published by the International Development Research Centre
PO Box 8500, Ottawa, ON, Canada K1G 3H9

June 1995

MacKay, K.T.
Chinese Academy of Agricultural Sciences, Beijing CN
Chinese Academy of Fisheries Sciences, Wuxi CN


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


A microfiche edition is available.

Material contained in this report is produced as submitted to IDRC Books. Unless otherwise stated, copyright for material in this report is held by the authors. Mention of a proprietary name does not constitute endorsement of the product and is given only for information.
Contents

Preface ......................................................... vii

Introduction  Wang Hongxi  .................................. ix

Part I: Review and Outlook

Rice–Fish Culture in China: The Past, Present, and Future
Cai Renkui, Ni Dashu, and Wang Jianguo  ....................... 3

Rice–Fish Culture in China: Present and Future
Chen Defu and Shui Maoxing  .................................. 15

Scientific and Technological Development of Rice–Fish Culture in China
Zhang Rongquan  ................................................... 23

Development of Rice–Fish Farming in Guizhou Province
Shi Songfa  ......................................................... 31

Reforming Rice–Fish Culture Technology in the Wuling Mountains of Eastern
Guizhou Province
Chen Guangcheng  ................................................. 37

The Development of Rice–Fish Farming in Chongqing City
Xu Shunzhi  ......................................................... 43

Development of Rice–Fish Farming in Jiangsu Province
Xu Guozhen  ......................................................... 49

Rice–Fish Culture and its Macrodevelopment in Ecological Agriculture
Yang Jintong  ......................................................... 55

Value of the Rice–Fish Production in High-Yielding Areas of Yuyao City,
Zhejiang Province
Cao Zenghao  ......................................................... 63

Developing Rice–Fish Culture in Shallow Waters of Lakes
Wan Qianlin, Li Kangmin, Li Peizhen, Gu Huiying, and Zhou Xin 67
Part II: Patterns and Technology

Different Methods of Rice-Fish Farming
Nie Dashu and Wang Jianguo .................................. 77

New Techniques for Raising Fish in Flooded Ricefields
Wan Banghuai and Zhang Qianlong ............................ 85

Methods of Rice-Fish Culture and their Ecological Efficiency
Wu Langhu .......................................................... 91

Ridge-Cultured Rice Integrated with Fish Farming in Trenches, Anhui Province
Yan Dejuan, Jiang Ping, Zhu Wenliang, Zhang Chuanlu, and Wang Yingduo ......................... 97

Development of Rice-Fish Culture with Fish Pits
Feng Kaimao ....................................................... 103

Techniques Adopted in the Rice-Azolla-Fish System with Ridge Culture
Yang Guangli, Xiao Qingyuan, and He Tiecheng ........... 107

Semisubmerged Cropping in Rice-Fish Culture in Jiangxi Province
Liu Kaishu, Zhang Ningzhen, Zeng Heng, Shi Guoan, and Wu Haixiang ................................. 117

Rice-Azolla-Fish Symbiosis
Wang Zaide, Wang Pu, and Jie Zengshun ....................... 125

Economic and Ecological Benefits of Rice-Fish Culture
Li Xieping, Wu Huaixun, and Zhang Yongtai ................ 129

Cultivating Different Breeds of Fish in Ricefields
Wang Banghuai and Zhang Qianlong .......................... 139

Rice-Fish Culture in Ricefield Ditchponds
Luo Guang-Ang .................................................. 147

Techniques for Rice-Catfish Culture in Zero-Tillage Ricefields
Chen Huarong .................................................... 153

Demonstration of High-Yield Fish Farming in Ricefields
Cai Guanghui, Ying Yuguang, Wu Baogan, He Zhangxiong, and Lai Shengyong ..................... 163

Rice-Azolla-Fish in Ricefields
Chen Defu, Ying Hanquing, and Shui Maoxing ................ 169
Part III: Interactions

Material Cycles and Economic Returns in a Rice–Fish Ecosystem
Ni Dashu and Wang Jianguo ........................................... 177

Fish Culture in Ricefields: Rice–Fish Symbiosis
Xiao Fan ................................................................... 183

Ecological Effects of Rice–Fish Culture
Pan Yinhe .................................................................. 189

Ecological Mechanisms for Increasing Rice and Fish Production
Pan Shugen, Huang Zhechun, and Zheng Jicheng ........... 195

Rice–Azolla–Fish Cropping System
Liu Chung Chu .............................................................. 201

Effect of Fish on the Growth and Development of Rice
Li Duanfu, Wu Neng, and Zhou Tiansheng ................... 209

The Role of Fish in Controlling Mosquitoes in Ricefields
Wu Neng, Liao Guohou, Lou Yulin, and Zhong Gemei .. 213

A Comparative Study of the Ability of Fish to Catch Mosquito Larva
Wang Jianguo and Ni Dashu ........................................... 217

Ability of Fish to Control Rice Diseases, Pests, and Weeds
Yu Shui Yan, Wu Wen Shang, Wei Hai Fu, Ke Dao An,
Xu Jian Rong, and Wu Quing Zhai ............................... 223

Distribution and Residue of Methamidophos in a Rice–Azolla–Fish Ecosystem
Xu Yinliang, Xu Yong, and Chen Defu .......................... 229

Residue and Application of Fenitrothion in a Rice–Fish Culture System
Lou Genlin, Zhang Zhongjun, Wu Gan, Gao Jin, Shen Yuejuan,
Xie Zewan, and Deng Hongbing .................................. 237

Part IV: Economic Effects

Economic Analysis of Rice–Fish Culture
Lin Xuegui, Zhang Linxiu, and He Guiting .................... 247

Economic Research on Rice–Fish Farming
Jiang Ci Mao and Dai Ge ............................................. 253

Ecology and Economics of Rice–Fish Culture
Quing Daozhu and Gao Jusheng ............................... 259
Semisubmerged Cropping in Rice–Fish Culture in Jiangxi Province

Liu Kaishu,32 Zhang Ningzhen,32 Zeng Heng,32 Shi Guoan,33 and Wu Haixiang34

Most of the 0.5 million ha of croplands in Jiangxi Province are pit fields, ridged fields, alluvial fields, and low grounds near the lakeside. These areas make up about 20% of the total ricefields in Jiangxi, but they are mostly cold, waterlogged, middle- or low-yield plots. The high water table is mainly responsible for the poor drainage of accumulated water. Constant water saturation has turned the soil to gley, which is cold, infertile, acidic, poisonous and lacks oxygen. Under these conditions, water, nutrients, air, and temperature are unfavourable to the growth and development of rice. Most regions yield one crop of rice a year, i.e., middle–late rice, but yield is low. To transform these low-yielding lands and increase crop production, a semiarid rice production initiated by Professor Hou Guangjiong was introduced in 1986 into the mountainous area of Gannan Prefecture, Jiangxi Province. This method of semisubmerged cropping in rice–fish culture has been improved to suit local conditions and has increased crop yields.

Main Principles

This method makes drastic changes to the system of rice cropping: planting on mounds instead of in furrows, putting ridges and ditches side by side to change the conditions in the field and add an active layer, planting rice on dikes, and culturing azolla and fish in the ditches. The physical changes raise the temperature of the soil and water, speed the catabolism of organic matter and the release of nutrients, and decrease the effect of toxic substances. As a result, seedlings revive sooner after transplanting, grow quickly, and have more white roots.

This method of rice–fish culture can turn single-crop agriculture into a double or multiple-harvest system and the slack winter season into a busy time. It is an excellent model of ecological agriculture that is applicable in all districts.

32 Jiangxi Agricultural University, Nanchang, Jiangxi Province.

33 Agricultural Administration Bureau, Ruijin County, Ruijin, Jiangxi Province.

34 Land Administration Bureau, Shangyou County, Shangyou, Jiangxi Province.
Continuous Nontillage

After the topsoil is ploughed for the first time, ridges and ditches are constructed side by side in the fields. Rice is planted on the ridges and fish are cultured in the ditches. Thereafter, the topsoil is not ploughed or harrowed to ensure that the active top layer is not destroyed. The soil does not become a caked mass; it grows softer with time. If the topsoil is ploughed, pockets of air and water capillaries in the soil are blocked. This decreases the percolation ratio, destroys the soil structure and the balance of water, nutrients, air, and temperature, and, as a result, reduces crop yields.

Continuous Ridge Tillage

Ridge tillage raises both the temperature of the water and soil and the oxidation-reduction potential of the soil. It activates soil nutrients and reduces toxic substances. This stabilizes the water, nutrients, air, and temperature and makes conditions more suitable for the growth and development of rice.

Continuous Infiltration

Capillary water in the soil is the only form of water that contains available nutrients and can flow freely, aerate the soil, and conduct heat. The key to semisubmerged cropping is improving the hydrological system of the soil. The continuous infiltration of capillary water aerates the soil, conveys nutrients, and prevents the soil from becoming a caked mass. The water level must be controlled according to the growth of the rice and the needs of the fish.

Demonstration and Application

No Tillage, Rice on the Ridge, Fish in the Ditch

Experiment were carried out for the first time in 1986 in Longhui Village, Nankang County, Ganzhou Prefecture, in cold, waterlogged mountain fields with an area of 0.3 ha. In 1987, the area was increased to 2 ha. Experiments were also carried out in lateritic low-yield plots at Luoding Village, Xingjiang County, and in a waterlogged lowland area near the lakeside at the Dongfeng Branch Farm of the Hongxing State Reclamation Farm. The total experimental area in these two areas was about 1.3 ha. In 1988, the method was popularized in over 1 330 ha in several counties (Ruijing, Nankang, Shicheng, Xingfeng, and Shangyou). In Ruijing County alone, there were 667 ha. Rice and fish were equally emphasized. In a few of the experimental plots, azolla was also cultured. The method was extended by the Agriculture, Animal Husbandry and Fish Department to an area of 200 ha in the counties of Fuzhou Prefecture.
Table 1. Output (kg/ha) of rice–fish culture (rice-on-ridge ROR; rice-on-bed ROB) compared with output (kg/ha) of conventional flat cropping (CONV). Values of output expressed as CNY.

<table>
<thead>
<tr>
<th></th>
<th>ROR</th>
<th>CONV</th>
<th>Increase</th>
<th>ROB</th>
<th>CONV</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice yield</td>
<td>10896</td>
<td>8673</td>
<td>2223</td>
<td>7504</td>
<td>6825</td>
<td>680</td>
</tr>
<tr>
<td>Value of rice</td>
<td>3886</td>
<td>3456</td>
<td>430</td>
<td>2979</td>
<td>2554</td>
<td>425</td>
</tr>
<tr>
<td>Value of fish</td>
<td>2012</td>
<td>0</td>
<td>2012</td>
<td>1539</td>
<td>0</td>
<td>1539</td>
</tr>
<tr>
<td>Total value</td>
<td>5898</td>
<td>3456</td>
<td>2442</td>
<td>4518</td>
<td>2554</td>
<td>1964</td>
</tr>
</tbody>
</table>

Table 2. Fish output (kg/ha) and economic benefits of two new methods (CNY/ha).

<table>
<thead>
<tr>
<th>Number of Households</th>
<th>Fish Output</th>
<th>Breeding Cost</th>
<th>Net Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice-on-ridge, fish-in-trench</td>
<td>8</td>
<td>3333.0</td>
<td>885.0</td>
</tr>
<tr>
<td>Rice-on-bed, fish-in-trench</td>
<td>6</td>
<td>1288.5</td>
<td>109.5</td>
</tr>
<tr>
<td>Difference</td>
<td>—</td>
<td>2044.5</td>
<td>775.5</td>
</tr>
</tbody>
</table>

Rice on the Bed, Fish in the Ditch

In 1987, this method was demonstrated on 2.8 ha in Shangyon County, Ganzhou Prefecture. The method features a wide ridge (0.8–1.2 m) that is constructed after the topsoil is ploughed. Rice is planted 13–17 cm apart on beds in rows that are 20 cm apart; fish and azolla are cultured in the ditch.

Benefit Analysis

Because management of agricultural production is presently carried out by individual households, the experiments, demonstrations, and applications were arranged at the household level. During the entire production period, technicians were sent to the areas to provide technical advice, conduct quality inspections, and observe and record results. The results are analyzed and compared in Tables 1–3.

Compared with conventional flat cropping, there were considerable increases in rice output and income from fish whether the rice-on-ridge or the rice-on-bed method was used. For example, 11 households used the rice-on-ridge method.
Table 3. Comparison of economic benefits of different combinations of fish species reared using the rice-on-ridge, fish-in-trench method.

<table>
<thead>
<tr>
<th></th>
<th>Area (ha)</th>
<th>Cost (CNY/ha)</th>
<th>Output Value (CNY/ha)</th>
<th>Net Income (CNY/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass carp</td>
<td>0.21</td>
<td>199.2</td>
<td>698.4</td>
<td>499.2</td>
</tr>
<tr>
<td>Common carp</td>
<td>0.31</td>
<td>38.2</td>
<td>651.0</td>
<td>612.8</td>
</tr>
<tr>
<td>Grass carp, common carp, and silver carp</td>
<td>0.14</td>
<td>889.4</td>
<td>2988.9</td>
<td>2099.5</td>
</tr>
<tr>
<td>Grass carp, common carp, and variegated carp</td>
<td>0.10</td>
<td>501.0</td>
<td>2299.9</td>
<td>1798.9</td>
</tr>
<tr>
<td>Grass carp, common carp, silver carp, and variegated carp</td>
<td>0.28</td>
<td>1258.4</td>
<td>4190.1</td>
<td>2931.7</td>
</tr>
</tbody>
</table>

Their average rice output increased by 2223 kg/ha (range 420–7140 kg/ha) and average net income from fish was CNY2010/ha (range CNY450–4935/ha). When the value of the fish and the increased amount of rice were both counted, the total rate of increase in value was 36.5–216.9% (average 86.3%). In another four households that used the rice-on-bed method, the increase in rice production was 680 kg/ha (range 530–990 kg/ha) and the net value of the fish was CNY1540/ha (range CNY531–3170/ha). The total net value of fish and rice increased by 76% (Tables 1 and 2).

The rice-on-ridge method is superior to the rice-on-bed method because it improves the ecological environment of the farmland (and enhances the growth of rice) and because it has a larger area of water, which is favourable for fish breeding. Higher economic benefits were obtained from the rice-on-ridge method when mixed species of fish, instead of a single species, were raised (Table 3).

Soil Improvement

Professor Hou Guangjiong has reported many improvements in the soil using the rice-on-ridge, fish-in-trench, no-tillage method of semiarid rice cultivation. Preliminary observations, suggest that unit weight of the soil decreases, temperature increases, and that the soil contains more organic matter, total nitrogen, available nitrogen, phosphorus, and potassium (in some cases, there was a tendency toward less total phosphorus compared with conventional flat cropping) (Tables 4–6).
Table 4. Reduction in soil unit weight (g/cm³) as a result of semiarid fish culture.

<table>
<thead>
<tr>
<th>Household</th>
<th>Semiarid Fish Culture</th>
<th>Flat Cropping</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zhu Longpeng</td>
<td>1.11</td>
<td>1.21</td>
<td>0.10</td>
</tr>
<tr>
<td>Zhu Changrui</td>
<td>0.96</td>
<td>0.98</td>
<td>0.02</td>
</tr>
<tr>
<td>Zhu Qiusheng</td>
<td>0.84</td>
<td>1.14</td>
<td>0.30</td>
</tr>
<tr>
<td>Zhu Xiaoping</td>
<td>0.85</td>
<td>0.93</td>
<td>0.08</td>
</tr>
<tr>
<td>Zhu Changfa</td>
<td>0.74</td>
<td>1.01</td>
<td>0.27</td>
</tr>
<tr>
<td>Lin Yuanxiao</td>
<td>0.84</td>
<td>0.95</td>
<td>0.11</td>
</tr>
<tr>
<td>Lin Chuanrong</td>
<td>0.98</td>
<td>1.00</td>
<td>0.02</td>
</tr>
<tr>
<td>Lin Yuanrong</td>
<td>0.97</td>
<td>0.99</td>
<td>0.02</td>
</tr>
<tr>
<td>Mean</td>
<td>0.91</td>
<td>1.03</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Remaining Problems

In experiments and demonstrations, the semiarid rice-on-ridge, fish-in-trench method has remarkably increased production and income and improved soil conditions. In 1989, the Prefectural Department of Ganzhou planned to apply the new method on 33,330 ha. Farmers who had become aware of the benefits of the method were happy. But, to extensively disseminate any new technique, potential problems should be examined and addressed.

Farmers do not believe that rice can be grown without ploughing the field. For thousands of years, rice has been planted in water using the flat basin irrigation cropping method. Ricefields with ridges are new. Most farmers doubt that the rice plants can absorb water and nutrients when they are planted on the ridges. Some farmers also complain that the ridges make it difficult for them to put their threshing tubs and machines in the fields at harvest time. More demonstration and extension efforts are needed to overcome these problems.

Many places have no previous experience with raising fish in ricefields. There are also some social problems. Fish in the fields are often stolen, especially in cold, waterlogged fields that are usually located in remote mountain areas. Farmers worry about this. Local governments must strictly enforce the law to protect farm production from theft. The villagers could also develop some protective measures.

The farming activities in the new method (e.g., digging trenches, forming ridges, clearing mud from the trenches, and applying fertilizer) require much labour. In Longhui Township, Nankang County, a small iron spade that was light and handy for clearing mud from trenches was popularized. Labour-saving tools or devices
Table 5. Soil temperatures (°C) at different depths with different cropping systems.

<table>
<thead>
<tr>
<th>Households</th>
<th>Time</th>
<th>0-10 cm</th>
<th>10-20 cm</th>
<th>0-10 cm</th>
<th>10-20 cm</th>
<th>0-10 cm</th>
<th>10-20 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zhu Longpeng</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>May 11 11:00</td>
<td>24.5</td>
<td>24.2</td>
<td>24.1</td>
<td>23.7</td>
<td>0.4</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>May 14 10:00</td>
<td>23.7</td>
<td>23.6</td>
<td>23.4</td>
<td>23.2</td>
<td>0.3</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>May 17 10:00</td>
<td>25.0</td>
<td>24.8</td>
<td>24.6</td>
<td>24.5</td>
<td>0.4</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>24.4</td>
<td>24.2</td>
<td>24.0</td>
<td>23.8</td>
<td>0.4</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Zhu Changgui</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>May 11 12:00</td>
<td>24.5</td>
<td>24.3</td>
<td>24.0</td>
<td>23.8</td>
<td>0.5</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>May 14 11:00</td>
<td>23.9</td>
<td>23.7</td>
<td>23.5</td>
<td>23.2</td>
<td>0.4</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>May 17 11:00</td>
<td>25.1</td>
<td>24.9</td>
<td>24.5</td>
<td>24.3</td>
<td>0.6</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>May 19 11:00</td>
<td>21.0</td>
<td>20.8</td>
<td>20.5</td>
<td>20.3</td>
<td>0.5</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>23.6</td>
<td>23.4</td>
<td>23.1</td>
<td>22.9</td>
<td>0.5</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Zhu Changfa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>May 11 11:00</td>
<td>25.0</td>
<td>24.8</td>
<td>24.6</td>
<td>24.4</td>
<td>0.4</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>May 14 11:00</td>
<td>24.0</td>
<td>23.7</td>
<td>23.5</td>
<td>23.3</td>
<td>0.5</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>May 17 11:00</td>
<td>25.1</td>
<td>24.9</td>
<td>24.5</td>
<td>24.3</td>
<td>0.6</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>May 19 14:00</td>
<td>21.4</td>
<td>21.3</td>
<td>21.0</td>
<td>20.7</td>
<td>0.4</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>23.9</td>
<td>23.7</td>
<td>23.4</td>
<td>23.2</td>
<td>0.5</td>
<td>0.5</td>
<td></td>
</tr>
</tbody>
</table>

Table 6. Analysis of soil nutrients (semiarid SA; conventional C).

<table>
<thead>
<tr>
<th>Organic Matter</th>
<th>Total N</th>
<th>Total P</th>
<th>Available N</th>
<th>Available P</th>
<th>Available K</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SA</td>
<td>C</td>
<td>SA</td>
<td>C</td>
<td>SA</td>
</tr>
<tr>
<td>(1)*</td>
<td>4.30</td>
<td>3.49</td>
<td>0.146</td>
<td>0.102</td>
<td>0.019</td>
</tr>
<tr>
<td>(2)</td>
<td>4.91</td>
<td>3.34</td>
<td>0.111</td>
<td>0.115</td>
<td>0.007</td>
</tr>
<tr>
<td>(3)</td>
<td>4.62</td>
<td>2.60</td>
<td>0.116</td>
<td>0.094</td>
<td>0.014</td>
</tr>
<tr>
<td>(4)</td>
<td>4.46</td>
<td>3.46</td>
<td>0.165</td>
<td>0.113</td>
<td>0.007</td>
</tr>
<tr>
<td>(5)</td>
<td>3.42</td>
<td>2.79</td>
<td>0.114</td>
<td>0.100</td>
<td>0.013</td>
</tr>
<tr>
<td>(6)</td>
<td>4.30</td>
<td>3.66</td>
<td>0.149</td>
<td>0.138</td>
<td>0.012</td>
</tr>
<tr>
<td>Avg</td>
<td>4.34</td>
<td>3.21</td>
<td>0.134</td>
<td>0.110</td>
<td>0.012</td>
</tr>
</tbody>
</table>

* Households were (1) Zhu Longbin, (2) Zhu Changrui, (3) Zhu Longze, (4) Zhu Xiaoping, (5) Zhu Xidi, and (6) Lin Yuan Xiao.
for trench digging, ridge forming, and row fertilization need to be developed. When a new technique is applied in a large area, farmers, because of their different levels of understanding, sometimes fail to follow the technical requirements for certain farming activities. Because of this, not only should extension and guidance be stressed, but input supplies, such as chemical fertilizers and pesticides, must also be made available.