Integrated rice-fish culture

Training toolkit

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AICCRA
Accelerating the Impact of CGIAR
Climate Research for Africa

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About AICCRA

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Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA) is a project that helps deliver a climate-smart African future driven by science and innovation in agriculture. It is led by the Alliance of Bioversity International and CIAT and supported by a grant from the International Development Association (IDA) of the World Bank. Explore our work at **aiccra.cgiar.org**

Contents

Glossary

Breeding	The reproduction process of male and female fry
Broodstock	Mature parents (male and female) ready for breeding
Stocking	Releasing fry or fish into a waterbody
Fry	Baby fish
Fingerlings	Larger than fry, about the size of a finger

1. Introduction

In Africa, increased reliance on fertilizers and pesticides in rice production has proven unsustainable and ineffective because of several factors: soil depletion, pesticide-induced insect pest outbreaks, the development of pesticide-resistant pests, the rising cost of pesticides and fertilizers, and the effects of pesticides and fertilizers use on human health and the environment. One potential solution to this problem is the integrated rice-fish system, which offers a wide range of food, income, nutrition and environmental benefits. The system ensures not only an appropriate supply of carbon, but also an adequate amount of animal protein, and it can significantly boost human nutrition because of the high levels of minerals and vitamins in fish. By following complementary land and water management procedures, the integrated rice-fish system can improve diversification, intensification, production, profitability and sustainability. In doing so, it would reduce the use of fertilizers and pesticides, and strengthen the economic, environmental and social sustainability of rice-based systems.

As in most African countries, however, the integrated rice-fish system remains marginal in Mali because of socioeconomic, environmental, technological and institutional constraints. As part of its overall goal of strengthening the resilience to climate change for several hundred thousand producers in Mali, the Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA) project hopes to change this. It has identified the integrated rice-fish system as a priority technology to validate and scale up within the country.

Rice monoculture remains the main farming system in Mali. However, the system does not make full use of the carrying capacities of the country's land and water resources. Currently, integrated rice-fish farming represents only 5% of rice-based systems in Mali, but it remains a promising option, as it results in better resource use, crop diversity and productivity, and improved quality and quantity of food produced.

For fish culture, whether in combination with rice cultivation or not, turning a profit hinge on fry and feed availability, good water quality management, and proper technical and financial management. Rice cultivation requires water, field preparation, seedlings, fertilization, weeding, pest and disease control, and timely harvesting. We developed this toolkit with all of this in mind to strengthen the capacity of stakeholders in integrated rice-fish farming systems in Mali.

1.1. Rice production in Mali

There is a variety of paddy cultivation in Mali and diversification in ecosystems, duration and production. The regional climate in different parts of the country influences the texture of the soil and how long it can hold water, as well as germination, growth, harvesting and variety selection. Paddy cultivation includes many activities: delimitation of the field, site cleanup, site ploughing, site leveling, pre-irrigation, seed establishment (whether direct seeding or transplanting after nursery), plot management activities (irrigation, fertilizer application, weed management), harvests, and post-harvest management. The soil should have a high clay content, significant sunlight and sufficient water availability. Harvesting at the right time is essential for the next steps, which include husking and polishing to process the rice. Rice yields vary from 4 to 6 t/ha depending on the variety and ecosystem.

1.2. Integrated rice-fish farming and its benefits

Integrated farming is a food production system in which fish are cultured concurrently or alternately with rice cultivation. Several studies have shown the benefits of integrating fish and rice: Matteson 2000; Berg 2001; Mustow 2002; Halwart and Gupta 2004; Giap et al. 2005; Ahmed et al. 2007; Nhan et al. 2007.

The benefits of integrated rice-fish farming include the following:

- improved soil fertility from increasing the availability of nitrogen and phosphorus.
- water aeration from the movement of fish
- integrated pest management
- the control of aquatic weeds and algae, which can carry diseases
- increased plankton, periphyton and benthos production because of the presence of rice plants
- lower water temperatures for fish during the summer because of the shade that rice plants provide
- diversified foods (rice and fish) and income sources.

2. Farming fish in a rice field

2.1. Plot selection for an integrated rice-fish system

Farmers should consider the following criteria when selecting a plot for culturing fish and cultivating rice together:

- A smaller plot is much easier to manage than a larger plot.
- The texture of clay or clay loam soil is better.
- The land should be fertile with organic matter.
- A soil pH 6–7.5 is good for both rearing fish and growing rice.
- The site should have an available water source and proper drainage.
- The plot should be exposed to sunlight for most of the day.
- An adequate flow of wind is also necessary.
- The plot must be easily accessible.

2.2. Selecting fish species and rice varieties

Tilapia and carp are the main fish species cultured in integrated rice-fish farming, as it is possible to breed both naturally in a rice field. This toolkit focuses on techniques for breeding and culturing tilapia. Reasons to select tilapia as the culture species in an integrated rice-fish system include the following:

- highly adoptable in a diversified environment
- breeds easily and grows fast
- eats both natural food available in the plot as well as supplementary pellet feed
- highly resistant to disease
- tolerates poor water quality
- high consumer preference
- low feed conversion ratio (FCR)
- affordable production cost and market price.

Selecting a rice variety depends on the regional climate and availability of seed. Wassa, adny, gambiaka, kokoni 2, adny11, nenekala, nionoka and nerica are common rice varieties in Mali. For paddies, first planting begins in January and harvest happens in May, while second planting starts in June and then the harvest in November.

2.3. Preparing the plot

2.3.1. Constructing the plot and ditch

A small plot is easiest to manage in integrated rice-fish farming. Having a sloped plot helps distribute water in both the plot and the ditch. There should be 5 cm difference between the area near the inlet and the area around the outlet. The ditch should either be on one side or around the entire plot, though a combination of the two will make it easier for the fish to move freely (Figure 1a). In some regions, farmers have a wider ditch on one side (Figure 1b).

The slope and wide crest make the dike more stable. The dike should rise at least 0.5 m above the plot. On one side, the width of the ditch should be 2 m and the depth 1 m, while the ditches around the other three sides of the plot should be 0.5–1 m wide and 1 m deep. The larger ditch should be located in the lower part of the plot. Having a plot with an inlet and outlet for watering is good for both fish culture and rice cultivation. The area of the ditch should be 10% or more of total rice plot. Using machines such as an excavator and power tiller can accelerate these activities.

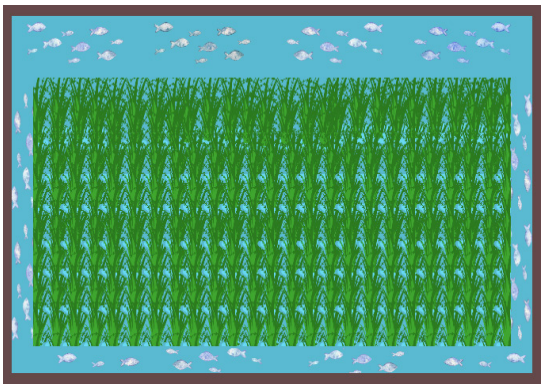

***Figure 1a**. A rice field with a four-sided ditch.*

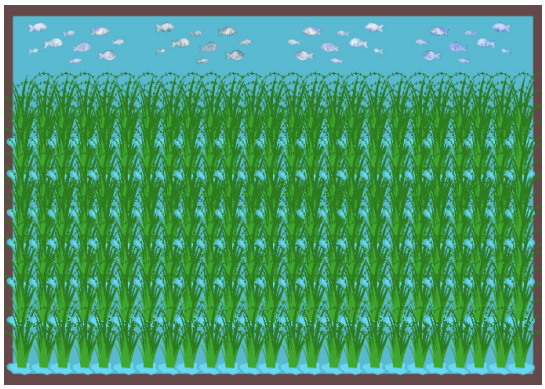

***Figure 1b**. A rice field with a ditch on one side.*

2.3.2. Preparing the paddy field

When starting a new crop, dry the plot and ditch properly. Plowing, clod crushing, puddling and leveling are all essential to prepare a plot. This improves the porosity of the soil and therefore helps increase the effects of fertilizer to promote the growth of roots and to minimize the growth of weeds at the beginning of the plant growth stage. It also helps break the cycle of disease and pests. After preparing the land, transplant young and healthy rice seedlings that are 15 – 21 days, from the seed bed to the plot at three to four seedlings per hill. The seed bed is generally located in a corner of the paddy or previously cultivated field, near the access point for irrigation.

2.3.3. Weeding

Weeding is important for both fish and rice, especially during the land preparation, nursery and early crop growth stages for rice, but also during the breeding and nursery stages for fish. However, frequent inspection of the system is necessary to remove floating weeds from both the ditch and the plot. It also helps to grow the best quality rice. Weeds compete with rice plant and phytoplankton for the absorption of nitrogen and other nutrients. As such, applying the optimal dose of fertilizer will not work when there are weeds in the plot.

2.3.4. Liming the ditch

Although the use of lime or dolomite in paddy fields is limited in Mali, it is necessary to remove unwanted fish seed during plot and ditch preparation for a new culture cycle. Apply lime (CaO) to dried or partially wet soil in the ditch at 25–40 g/m^2.

2.3.5. Water management

It is important to maintain the water supply when culturing fish and cultivating rice. Make use of the inlet and outlet to help supply and distribute water properly at any time. Also, farmers must ensure that the water can pass through the paddy during flooding, water exchange in the dike and for other purposes. Maintain a water level of 4–6 cm at the top of the plot 7–10 days after transplanting the rice, and continue until the milky stage. For integrated rice-fish farming, the water level should be no lower than 1.6 cm (1 m in the ditch and 6 cm at the top of the plot). When beginning to stock the fish, maintain a water level of 1 m or higher in the ditch. After harvesting the rice, increase the water level to 1.6 m or higher, depending on the holding capacity of the dike.

2.3.6. Fertilization

Fertilization is necessary for cultivating a high yielding variety (HYV) of rice as well as for boosting plankton density in the water for fish culture. The stability of plankton depends on the amount of sunlight, which helps in photosynthesis. For cultivating rice, the recommended fertilizer doses are 100 kg/ha when using a nitrogen-phosphorus-potassium (NPK) fertilizer (12-24-18) and 150 kg/ha for urea, at 46% nitrogen. Apply NPK as a base layer when transplanting the rice. For urea, apply half of the recommended quantity 20 days after transplanting the rice and the other half 10 days later. For the ditch, apply the fertilizer at the same time and at a similar dose.

Before determining the fertilizer dose, have the nutrient content of the soil analyzed at a nearby laboratory. Lime the ditch first and then the inlet. Apply the fertilizer 3–4 days later.

Examples of inorganic fertilizers include NPK, urea, diammonium phosphate and triple super phosphate, while organic fertilizers include compost or fermented products. Both types help to increase productivity of the plot as well as the availability of natural food, in the form of phytoplankton and zooplankton, which reduces the amount of supplementary feed needed and therefore the feed cost.

There are several ways of measuring the amount of natural food in the water. Taking a Secchi disk reading is an easy way to measure the need for fertilizer by measuring the phytoplankton density in the water. A reading of 25–30 cm in the morning, taken between 09:00 and 11:00 in proper sunlight, suggests that the pond water contains enough natural food, so additional fertilization is not required.

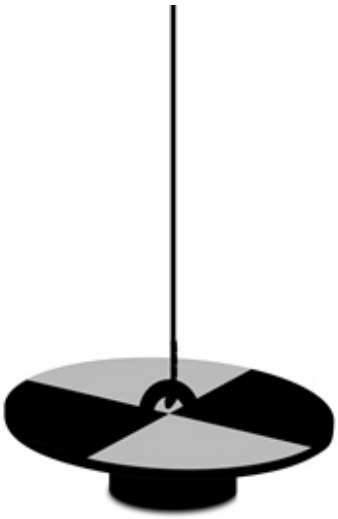

***Figure 2**. Secchi disk.*

Measure the amount of zooplankton by dragging a small filter cloth through the water column or by screening the water using a fine mesh net. Examine the zooplankton trapped on cloth or screen and then transfer the mix of zooplankton into a transparent glass of water and look at it against the sunlight. If more than five zooplankton are visible in the glass, the water has enough zooplankton. Always apply fertilizer when the weather is sunny.

Dilute all types of inorganic fertilizers in water before applying them in the pond, preferably in the morning on a sunny day. However, be sure to soak phosphate fertilizer in water 1 day before application.

Apply additional inorganic fertilizers in the ditch as follows:
- Apply 2.4 kg of urea for 1000 m^2 directly into the water.
- Apply 1.6 kg of dissolved phosphate for 1000 m^2 in the water.

Do not use inorganic fertilizer when there are fry in the ditch. During the culture period, only use fertilizer when the fish weigh more than 50 g, and even then use only half of the recommended dose.

Instead of unavailability of inorganic fertilizer, the following organic fermented fertilizer can be used.

***Table 1**. An example of a formula for organic fertilizer using organic and fermented products.*

Ingredients	Amount	Remarks
Soybean meal or mustard oil cake or similar product	1.25 kg	Mix these ingredients together and cover them in a pot for 20–24 hours. Then sieve and spread the mixture over the ditch during the day.
Rice bran	2.5 kg	
Molasses (byproduct of sugar mill or alternative)	2.5 L	
Yeast	2–3 teaspoons	
Water	8 L	

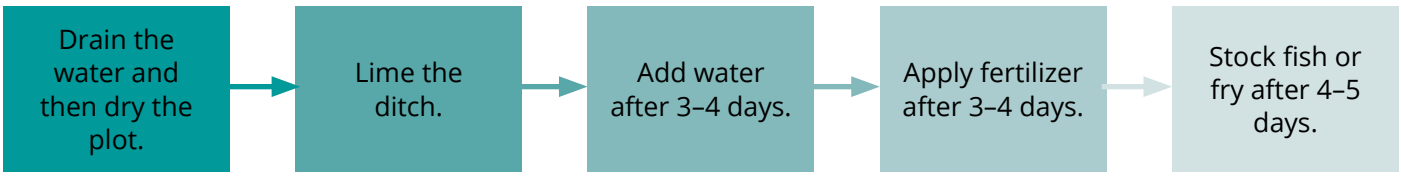

***Figure 3**. Sequence of plot preparation for fish culture.*

3. Concepts

3.1. Fish breeding

Fish breeding is the process of producing fry. It comprises three main steps when done in a rice field: preparing the rice plot and ditch, stocking male and female fish for reproduction, and employing proper feeding and management procedures to ensure a high survival rate of the fry.

3.2. Fish nursery

A fish nursery is for producing large fingerlings. It comprises three main steps when done in a rice field: preparing the rice plot and ditch, stocking fry, and feeding and management for an adequate growth of the fry.

3.3. Fish grow-out

Fish grow-out is the process of producing food fish for consumers. It comprises four main steps when done in a rice field: preparing the rice plot and ditch, stocking large fingerlings, feeding and management, and harvesting fish for sale and consumption.

***Table 2**. A summary of the three stages of integrated rice-fish farming.*

Field type	Activity	Output
Fish breeding in a rice field	1. Prepare the rice plot and ditch. 2. Stock male and female fish. 3. Follow proper feeding and management procedures.	• Fish fry production
Fish nursery in a rice field	1. Prepare the rice plot and ditch. 2. Stock the fry. 3. Follow proper feeding and management procedures.	• Large fingerling production • Selling additional fingerlings to other farmers, or stocking them in another rice field for culture
Fish grow-out in a rice field	1. Prepare the rice plot and ditch. 2. Stock large fingerlings. 3. Follow proper feeding and management procedures. 4. Harvest the fish.	• Food fish production for consumers

4. Fish breeding and fry production in rice fields

There is a limited number of fish hatcheries in Mali, and the broodstock they contain are not genetically improved. As such, this toolkit suggests farmers to select quality local broodstock and rear them in a pond or rice field for fry production.

4.1. Advantages

There are several advantages in breeding and producing fry in a rice field:

- It produces mixed-sex fry of similar size and age groups.
- It is a low cost method of producing fry.
- The fry are acclimated to the rice field environment.
- It produces a quick return on investment. For example, 50 female and 25 male tilapia in a 1000 m^2 rice field plot can produce 20,000 to 30,000 quality fry within 3–4 months.
- It ensures that quality fry are available year-round, which helps farmers nurse fry in their rice fields to produce large fingerlings.

4.2. Selecting a rice plot

To breed and produce mixed-sex tilapia fry in a rice field, it is important to select a small plot with approximately 1000 m^2 of surface area. Choose a plot that is close to the homestead area to make it easy to observe breeding, production and harvest. The other criteria are the same as described in Section 2.1.

4.3. Preparing the plot

Prepare the plot following the procedure outlined in Section 2.3.

4.4. Collecting broodstock

To produce quality fry, use improved fish strains of known origin. Fry from improved strains have higher growth performance, as well as other traits like greater feed efficiency and disease resistance. In a hatchery, it is important to follow better management practices to avoid inbreeding and other negative practices, such as negative selection and poor nutritional management, both of which lead to poor fish performance.

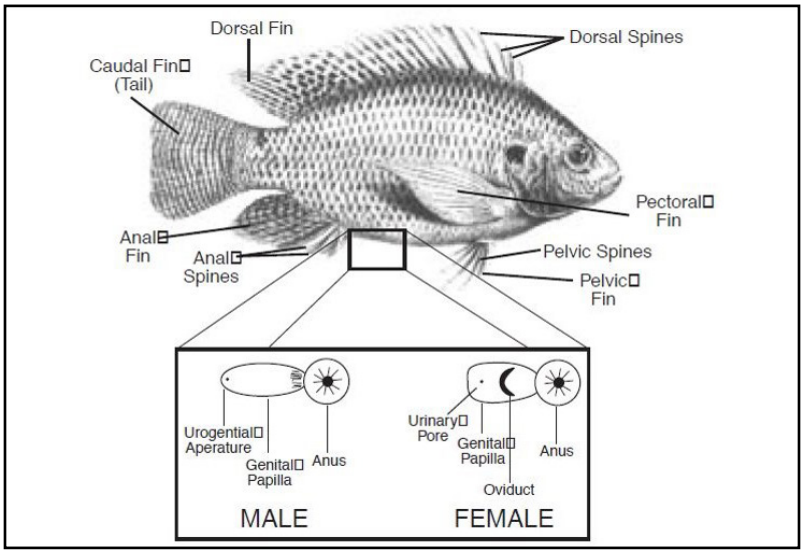

***Figure 4**. Tilapia anatomy. **Source**: Thomas and Micheal 1999.*

4.5. Identifying broodstock

4.5.1. Male broodstock

Mature males have two openings around the anal region: one is at the distal end of the papilla, which is elongated relative to what is found in females, and the other is a conspicuous oval anal opening. A mature male will release milt when slight pressure is applied to the abdomen. Generally, males can be distinguished by their red fins. However, some females also have colored fins, so it is important to confirm the sex according to their genital openings to minimize errors when sexing broodfish (Basiita 2020).

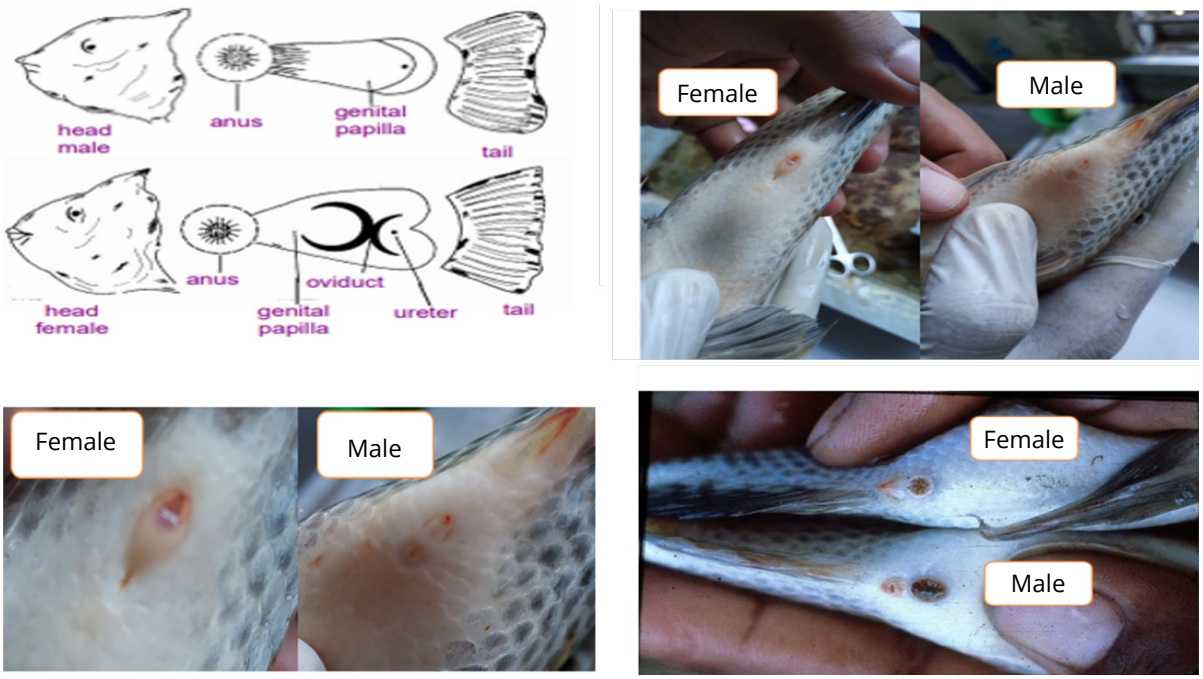

***Figure 5**. Identifying male and female tilapia.*

4.5.2. Female broodstock

Female Nile tilapia have three body openings: the anal opening, the urethra and an additional slit midway on the papilla (oviduct) through which eggs are released. When females are ready to spawn, their belly becomes round and soft, and the papilla and openings usually become reddish. The fish will release a small amount of eggs when slight pressure is applied on the abdomen. If a female has spawned before, her chin will appear yellowish (Basiita 2020).

4.6. Transporting broodstock

When stocking tilapia broodstock in a rice field, transport them carefully to avoid stressing the fish. For long distance transportation, fasting and showering the fry is sometimes necessary to acclimatize them to the rice field. If transporting broodstock in a container or polythene bags, fill them with one-third water and two-thirds oxygen. Fry weighing 200–250 g in total weight carried in 5 L of water can be transported as long as 10–12 hours. During transportation, take precautions to avoid high temperatures and tearing the bags.

***Table 3**. A guideline for transporting fry in oxygenated polythene bags (28 x 20 inches).*

Weight of fry (g)	Number of fry	Volume of water (L)	Travel time (hours)
1	500–600	8–10	10–12
2	250–300		
3–5	100–170		
5–10	50–100		
10–20	25–50		

4.7. Stocking broodstock in rice fields

In a rice field plot with approximately 1000 m^2 of surface area, stock 50 female and 25 male tilapia from improved strains and well-known sources. Each fish should weigh 250–300 g. Use the fish as broodstock for fry production for at least 1–2 years. On average, female tilapia can produce 600–800 fry three or four times per year.

4.8. Replacing broodstock

After 2 years, broodstock become too old to use for breeding, as their fecundity drops. So it is important for farmers using an integrated rice-fish system to replace them with new broodstock (250 to 300 g) to continue breeding and fry production. It is also important to prepare the plot, ditch and dikes after each 4-month production cycle—3 months with rice and rice followed by 1 month with only fish in the plot per cycle. This will ensure the best results in fry production.

4.9. Feeding broodstock

It is always important to feed broodstock and fry good quality supplementary feed to achieve high rates of success in fry production from a rice field. For broodstock, feed the fish twice a day at 2%–3% of their weight. For example, in a 1000 m^2 rice field with a total weight of 20 kg—50 female broodstock (250 g each) weighing 12.5 kg and 25 males (300 g each) weighing 7.5 kg—the total amount of feed required daily would be 400 g to 600 g spread across two feeding times.

High quality pellet feed will be water stable and have a balanced nutritional content according to the life stage of the fish and type of species. Farmers can prepare feed using locally available ingredients and by following prescribed formulas and production methods, as outlined in Section 7.3 and 7.5.

4.10. Producing and harvesting fry

Tilapia broodstock breed naturally in rice fields. Use a seine net or scoop net to start harvesting fry from the ditch about 1 month after stocking broodstock in the plot. Lowering the water level will force the fry to move into the ditch. Harvest fry regularly at 15-day intervals.

After completing the rice harvest and before transplanting the next rice crop, there is a 3–4 week gap when only the fish are in the plot. This is the time for farmers to harvest their fry from the plot. To harvest fry, drain all the water out of the plot and ditch. During this gap period, farmers can stock broodstock in hapas installed in the pond.

During the harvest, fry and fingerlings will be of different sizes and ages, so it is important to grade fry by size. Stock the smaller ones in hapas for nursing, and stock the larger ones directly in the rice field either for grow-out production or for sale to customers.

5. Nursery for producing large fingerlings

The nursery period lasts 3–4 months. Stock fry in the rice plot at a density of 2 fry/m^2. When the nursery period is over, transfer the fingerlings to a grow-out plot or maintain them in the same plot. One advantage of conducting the grow-out period in a different plot is that it allows farmers to manage their fish better, as the fry can grow into large fingerlings in a short period of time.

5.1. Acclimatizing and stocking fish in a nursery plot

It is necessary to acclimatize fry into the receiving water so that they can adjust to the different water parameters. This increases the survival rate in the receiving culture environment.

Follow these steps when acclimatizing fish:

- Float the container or bag holding the fry in the ditch water for 15–20 minutes.
- By hand, slowly replace the water in the container or bag with the water in the ditch.
- When the temperature between the water in the container or bag and the ditch water equalizes, slowly allow the fry to swim into the ditch.

5.2. Selecting a plot

Follow the same instructions outlined in Section 2.1.

5.3. Preparing the plot

Follow the same instructions outlined in Section 2.3.

5.4. Nursing fry in a rice field

For nursing fry, a rice plot of about 1000–2000 m^2 is easier to manage than larger plots. Nurse fry in the plot for 3–4 months at a stocking density of 2 fry/m^2. Be sure to maintain a water level of at least 5 cm higher than the rice plot itself.

5.5. Nursing fry in hapas

Nurse fry in hapas at a stocking density of 500–700 fry/m^3 for 25–45 days. Although nursing seems easy in hapas, it is necessary to clean the hapas regularly to ensure the water flows freely through them. Clean the hapas using a smooth brush to remove clogging, and install air stones for aeration in case of emergency. A pond is the best option for setting up hapas. However, farmers can also set them up in the deeper part of the ditch in a rice field. Hapa sizes vary depending on the pond, ditch and the farmer's capacity, but they should usually measure 3 x 2 x 1 m and be more than 1 m deep in a water depth of 1.5 m or more. Be sure to remove any leftover feed and fecal matter regularly from the hapa.

***Plate 1**. Installed hapas. **Source**: Basiita 2020.*

5.6. Feed and feeding methods

To enhance fish growth, balance the nutrients in the feed according to the growth stage of the fish. Follow the instructions for feed management outlined in section 7.

5.7. Harvesting large fingerlings

The harvesting time depends on the desired size of the fish, so periodical sampling is necessary to determine the weight of the fish and to set a harvest date. Farmers generally prefer tilapia weighing 25–30 g. However, fingerlings should be no larger than 10 g if raised in hapas set in a pond. To begin the harvest, drain the water from the rice field and then use a net to capture the fish.

Arrange to harvest the fish and the rice at around the same time. Harvest the rice plants first, after 80–150 days, and then the fingerlings before transplanting a new rice crop. Expect a survival rate of 60%–75%.

After harvesting the fingerlings, farmers can (i) transfer them to another rice field or pond to grow them into table fish, (ii) sell them to other farmers, or (iii) keep them in the same plot and reduce the stocking density to 1 fingerling/m^2.

6. Grow-out for producing food fish

6.1. Preparing the plot

Follow the same instructions outlined in Section 2.3.

6.2. Stocking large fingerlings

Stock fingerlings weighing at least 20 g at a density of 1 fingerling/m^2.

6.3. Feed and feeding methods

Feeding fingerlings a nutritionally balanced pellet feed is best for optimal growth within the desired period. As commercial feed is not available in Mali, farmers can make farm-made pellet feed to give to their fish. The production process is described in section 7. Feed the fish twice daily according to their weight ratio, and split the amount of feed between two feeding times: one in the morning, at 09:00–10:00, and the other in the afternoon, at 16:00–17:00.

6.4. Culture period

The grow-out period lasts about 4 months: 3 months with both rice and fish and 1 extra month with only the fish in the plot. Use the extra month to prepare the plot for the next rice crop. It is possible for farmers to culture three cycles of fish alongside three cycles of rice every year.

6.5. Benefits of using the extra month

During the 1 month gap period between rice cycles, the fish will grow faster from eating the detritus of decomposed rice plants, which generates higher primary production. In turn, the fish will also produce more fecal matter that will serve as organic fertilizer for the next rice crop.

6.6. Fish production

One cycle of an integrated rice-fish system lasts 4 months. If the initial stocking density is 1 fingerling/m^2, with a 75% survival rate up to grow-out, farmers can expect to harvest 750 fish at an average weight of 150 g. Overall, this amounts to 112 kg per cycle in a 1000 m^2 plot, or 1120 kg/ha per cycle, and approximately 3360 kg/ha per year over three culture cycles.

7. Feeding fish

7.1. Natural food

Natural food for fish is produced in the water through different physical and chemical processes in the air, water, and soil or sediment. By applying external nutrients such as fertilizer, however, farmers can accelerate natural feed production in a pond. Fertilizer mainly accelerates the production of phytoplankton, which in turn enhances the production of zooplankton. Both are essential, along with supplementary feed, for proper growth and survival of fish.

7.2. Supplementary feed for optimal growth

Supplementary feed is an external diet given to fish so that they can obtain their maximum growth and yield. Ingredients include rice bran, oil cake, wheat flour, fishmeal, etc., or their combinations. Compounded pellet feed, produced mainly using a pellet mill or extruder, is a nutritionally balanced supplementary feed that contains different combinations of ingredients to provide the required levels of nutrients according to the fish species and life stage. Farmers should give their fish supplementary feed daily.

7.3. Producing pellet feed

As there is a lack of commercial pellet feed in Mali, farmers can make their own using their own tools and local ingredients. One important item farmers will need is a mincer, which they can customize in a local workshop to include a long chamber, different sieve and other.

Farmers should follow these steps to produce their own feed:

1. Select and buy the ingredients, adding at least 10% extra to compensate for loss during processing.
2. Grind or pound the ingredients.
3. Sieve the powder to separate fine particles.
4. Measure a proportional mixture according to the formula.
5. Stir the mixture rigorously with about 5%–10% water.
6. Heat the mixture at 80°C–90°C for 30 minutes and mix it thoroughly so that the entire mixture is the same temperature.
7. Put the mixture in the pellet mill or mincer to produce the feed.
8. Dry the pellets in the sun or air.

Plate 2. Producing farm-made feed.

7.4. Nutrition for optimal growth

Ensure that the nutritional content of supplementary feed aligns with the requirements of the fish species and life stage. Otherwise, a deficit in dietary nutrients will slow growth, even if the feed is distributed properly.

***Table 4**. Nutritional requirements for tilapia.*

Species	Feed type	Nutritional value (%)							
		Moisture (Max)	Protein (Min)	Lipid/oil (Min)	Carbohydrate (Max)	Fiber (Max)	Ash (Max)	Calcium (Max)	Phosphorus (Min)
Tilapia	Larviculture	12	30	6	28	5	16	2.3	0.8
	Starter	12	28	6	30	7	18	2.1	0.7
	Pre-grower	12	27	5	32	7	18	2	0.6
	Grower	12	25	5	38	8	20	1.9	0.5
	Finisher	12	24	5	40	9	22	1.8	0.4

7.5. Selecting and formulating ingredients

Choosing quality ingredients is the most important part of the production process, as it is related to overall feed digestibility and price. An experienced nutritionist can help develop cost-effective recipes, as shown in Table 5.

***Table 5**. A sample recipe for farm-made pellet feed.*

Ingredients	Amount (%)
Cassava flour	10
Rice polish (Grade A)	20
Morgina seed meal/powder	10
Soybean meal (de-oiled)	18
Dried fish	17
Maggot meal	6
Salt	1
Soybean oil	1
Di-calcium phosphate / limestone (feed grade)	2
Molasses	10
Azolla	5
Total	100

7.6. Administering feed

Proper feed management is important for the fish to convert the feed into weight (meat). The feeding rate is the amount of feed that the fish require daily. It is dependent on the life stage of the fish, the weather, the amount of natural food in the water, and the overall health of the fish. As such, farmers need to observe their fish carefully both during and after feeding to detect any potential problems, such as feed refusal.

***Table: 6**. Example of Feeding rate for Broodstock.*

Average weight of Broodstock (gm)	Number of Broodstock (50 female and 25 male)	Daily feeding rate (% of weight)	Amount of feed (gm/ day)	Feeding frequency (Times /day)
250- 300	75	3	562-675	3

***Table: 7**. Example of Feeding rate for Nursing fry in hapa (1000 fry).*

Age of fry (day)	Average weight of fry (gm)	Daily feeding rate (% of weight)	Amount of feed (gm/day)	Feeding frequency (Times /day)
1-5	0.008 – 0.01	35%	2.8 -3.5	4
6-10	0.01 – 0.025		3.5 – 8.75	4
11-15	0.025 – 0.04		8.75 - 14	4
16-21	0.04 – 0.1		14-35	4

Note: The average weight of fry is influenced by quality of feed, surrounding environment, stocking density and strain of fish.

***Table: 8**. Example of Feeding rate for growing fish in nursey for fingerling production.*

Average weight of fry (gm)	Daily feeding rate (% of weight)	Feeding frequency (Times /day)
0.1-1	35-25	3-4
1-5	25-20	3-4
5-10	20-15	3-4
10-25	15-8	3-4

Table: 9. *Example of Feeding rate for growing food fish.*

Average weight of fish (gm)	Daily feeding rate (% of weight)	Feeding frequency (Times /day)
25-50	8.0-5.0	2
50-75	5.0-4.0	2
75-100	4.0-3.0	2
100-250	3.0-2.0	2
250-400	2.0-1.5	2
400-500	1.5-1.0	2

7.7. Acclimatizing fish to supplementary feed

Administer balanced supplementary feeds two or three times daily at the same time and same place in the ditch of the rice field. This practice will acclimate the fish to the supplementary feed within a week, and they will usually move to that specific point in the pond at the feeding times. However, make sure not to feed the fish when it is raining.

8. Controlling poaching

To control poaching, arrange to have a guard at night, and put some dry branches in the dich to prevent poachers from casting their nets in the pond.

9. Harvesting

9.1. Harvesting rice

When 80% of the grain panicles have matured, it is time to harvest the rice. Generally, HYV rice is ready to harvest within 130–140 days.

9.2. Harvesting fry from broodstock

Harvest the fry from the ditch by lowering or draining the water and then catching them with a fine mesh scoop or seine net, as outlined in Section 4.10.

9.3. Harvesting large fingerlings from the nursery

When tilapia reach 20–30 g, it is time to harvest them from the nursery in the rice field, as outlined in Section 5.7.

9.4. Harvesting large fish (table fish) from grow-out rice fields

Begin a complete fish harvest 1 month after harvesting the paddy. Once the rice has been harvested, raise the water level in the rice field 0.3–0.5 m, taking into account the dike's height and strength to hold water. Having a large area, high water level and organic fertilizer from the decomposition of rice plants will boost the amount of natural food in the water and enhance fish growth. Once the fish are ready to harvest, drain the water from rice field completely and then use a seine net to catch the fish.

10. Activity chart

***Table 10**. Culture calendar.*

Activities	Timeline											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Preparing the plot					■	■						■
Producing rice seedlings (separate plot)	■					■						
Transplanting rice seedlings (rice-fish plot)		■				■						
Releasing broodstock into the rice-fish plot	■											
Harvesting fry from the plot		■		■		■		■		■		■
Nursing fry in the rice field nursery and harvesting large fingerlings			■	■		■	■		■	■		■
Releasing large fingerlings and culturing them in the grow-out rice field (cycle 1)					■	■	■					
Releasing large fingerlings and culturing them in the grow-out rice field (cycle 2)								■	■	■		
Releasing large fingerlings and culturing them in the grow-out rice field (cycle 3)	■										■	■
Feeding	■	■	■	■	■	■	■	■	■	■	■	■
Fertilizing	■		■		■		■		■		■	
De-weeding		■		■		■		■		■		■
Sampling				■		■		■		■		■
Harvesting rice						■					■	
Harvesting fish	■						■			■		

11. Post-harvest management

11.1. Rice

After harvesting is complete, choosing the right moment for each post-harvest stage and using proper techniques are both essential for processing the rice and determining the quality of the final product. Post-harvest management includes drying the field, threshing, and drying the shed, as well as cleaning, grading, storing, weighing and milling the rice. The percentage and quality of the rice to be milled is strongly correlated with the moisture content of the paddy grain. The amount of moisture should be less than 15%, so it is important to dry the rice immediately after harvesting it, as too much moisture will turn the rice yellow and lead to mold outbreaks and sometimes even germination. Ensure the storage warehouse is built to prevent moisture from entering.

11.2. Fish

Do not feed the fish the day before the harvest. After catching the fish, clean them properly with clean water, and then transport them to the market, whether live, dead or dried. Drying can preserve fish for a long time, but it is important to use proper techniques to extend the shelf life of the fish and ensure they are safe for people to eat.

12. Recordkeeping

Maintaining proper records is important for the success of any farming business.

12.1. Harvest records

This involves keeping records of all daily activities, including fertilization, watering, de-weeding, liming, weather observation and feeding amount.

Table 11. *An example of a record book.*

Name of farmer:	
Address and mobile number:	
Location of rice plot:	
Rice field number: No. 4 (grow-out for fish)	

Basic information of the rice plot:			
Area:	1000 m^2	Ditch area:	100 m^2
Water level:	10 cm	Ditch water depth:	3.1 m
Fish species:	Tilapia	Rice variety:	Adny
Number of fingerlings:	1000	Initial weight of each fingerling:	20 g

Date	Number of culture days (after releasing fish into the plot)	Temperature (°C)	Type of weather	Type of fertilizer and amount (kg)	Weight of fish at sampling (g)	Feed amount (g)	Liming (kg)	De-weeding (yes/no and amount of time)	Water level in the ditch and plot (cm)	Remarks

12.2. Financial records

Maintain financial records of all transactions, including purchases, opportunity costs, expenses and revenues. This will help farmers track the profitability of their farm and provide them with a clear understanding of their equities, liabilities and net income.

Table 12. *Headings for financial records.*

Date	Purpose and item*	Cash account			Remarks
		Received	Paid	Balance	

Note: This can include paid purchases of fry, rice seeds, rice plants, fuel, labor, fertilizer and feed, as well as income earned from culturing fish and cultivating rice.

13. Economics of integrated rice-fish farming

13.1. Factors of profitability

The production cost of harvesting fish and rice depends on the lease value of the land, the labor wages, the price of the rice seed or plants, the price of the broodstock or fry, the cost of the fertilizer, the cost of renting and fueling the machines, the cost of the feed and the cost of electricity. Using HYV rice and genetically improved fish can decrease cultivation and culture time. This in turn will lower operating costs and increase yearly production, thus reducing the unit production cost of both rice and fish.

However, the selling price is different, as it is dictated by the market price at the time of sale. It depends on the local context, such as consumer preference for species, size and product type (dried, live or frozen fish).

13.2. Comparative profitability analysis

In an integrated rice-fish system, farmers can easily harvest fast-growing fish species like GIFT three times a year, if they use large fingerlings in their rice plot. We collected the following information after interviewing some of the farmers. Although some of this information might not be accurate, it can stand as an example of comparative profitability:

- average annual rice production: 8 t/ha (4 t/ha per cycle for two cycles in a year)
- average annual rice production in a 10% plot used almost exclusively for fish: 0.8 t/ha
- average selling price of rice: XOF 500/kg
- average annual tilapia production: 3.36 t/ha (three cycles in a year)
- average selling price of tilapia: XOF 1500/kg (150 g each).

Additional cost of fish culture: XOF 1,449,600

- feed cost: XOF 1,209,600 (2 FCR x 3360 kg of fish x XOF 180/kg of feed)
- fingerling cost: XOF 200,000 (10,000 fingerlings x XOF 20/fingerling)
- fertilizer cost: XOF 10,000
- labor cost for the dike (2 year depreciation): XOF 15,000
- land lease value (10% of 1 ha): XOF 15,000.

Income from integrated rice-fish culture in 1 ha:
(Price of harvested rice: XOF 3,600,000 + price of harvested fish: XOF 5,040,000) – (additional cost of fish culture: XOF 1,449,600 + production cost of rice: XOF 1,310,400) = XOF 5,880,000 net profit

Income from rice monoculture in 1 ha:
Price of harvested rice: (8000 kg x XOF 500/kg: XOF 4,000,000) – Production cost of rice: (8000 kg x XOF 182/kg: XOF 1,456,000) = XOF 2,544,000 net profit

14. Conclusion

Integrated rice-fish culture can be an economically profitable and environmentally friendly venture for farmers when better management practices are used. Having a fertile plot with plenty of sunlight, an available water supply and proper drainage are all important factors for both rice cultivation and fish culture. The recommended ditch area for culturing fish is 10% of the total rice plot. When selecting a fish species to culture, consider strains that are easily adoptable, fast-growing and highly efficient at converting feed to weight. Stocking fish of similar size and age and at an optimal density in nursery and grow-out rice plots will ensure good growth and reduce size variation come harvest time. To maintain the quality of the broodstock, farmers should arrange cohort breeding or replace their broodfish within 2 years.

A safe and reliable water supply is essential when using a rice plot. Maintain water levels of at least 1 m in the ditch and 5 cm in the plot. The natural productivity of water will produce natural food (phytoplankton and zooplankton) during the early stage of fish growth, and following proper scheduled fertilization will help maintain it. In addition to natural food, supplementing fish diets with nutritionally balanced pellet feed is important for optimal growth. Feed efficiency, both economically and nutritionally, depends on several factors: the quality and availability of local ingredients, the age of the fish, species-specific feed formulation, feed palatability, feed digestibility, pellet durability and production process.

For farmers, integrated rice-fish culture can provide them with four types of products to sell: rice, fry, large fingerlings (20–30 g) and table fish (150–200 g). In addition, keeping records will help farmers track their expenses and income on their way to earning profits.

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