MALAGASY INTEGRATED AQUACULTURE-AGRICULTURE

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1. Introduction

Aquaculture is one of the most relevant activities to fight poverty and hunger in Madagascar. The sector contributes to foreign revenues through exportation of seaweed and farmed shrimps, as well as to improve population incomes, food security and nutrition (FAO, 2008). Moreover, it has been identified as a promising sector for keeping pace of growing demand and overfishing pressure. Inland aquaculture, mostly finfish farming, is the dominant practice among small farmers but still, its production remains marginal compared to marine aquaculture and inland fisheries. In 2017, the Malagasy marine aquaculture produced 5 439 tonnes of shrimps and 17 407 tonnes of algae, and inland fisheries, 35 993 tonnes (FAO, 2019). In the meantime, freshwater finfish farming harvested only 5 390 tonnes (FAO, 2019). However, the potential of the sector is still largely untapped, with Madagascar having about 150 000 ha of lakes and lacustrine areas and 200 000 ha of irrigated paddy fields appropriate for fish farming, of which less than 20 percent are exploited (MRHP, 2015). One relevant way of increasing the national farming of freshwater fish, while benefiting from synergies, recycling and circular economy is to integrate fish farming into existing agricultural systems. Over the years, Madagascar farmers have championed this integrated aquaculture-agriculture by implementing several systems described in this article.

2. Rice-fish farming

The integration of aquaculture and agriculture is traditional and diverse in Madagascar but rice-fish farming is the most common and oldest practice. It consists in raising rice and fish together in the same irrigated field to obtain a fish crop in addition to the rice which remains the main production (Halwart and Gupta, 2004). Fish feed on the rice midge larvae, pest and other undesirable organisms for rice. Their excreta provides fertilization and their bioturbation behaviour increases the nutrient availability for plants such as nitrogen and phosphorus. Traditional rice-fish farming requires reasonable amounts of labour and inputs: farmers just trap wild fish entering water from irrigation canals, ditches and rice fields and let them grow until rice harvest or later. In some regions, another rice fish system was introduced, in which dykes are made high enough to retain a sufficient water depth for the fish. A canal is also dug in the field and used as fish refuge. Livestock manures can also be provided as a fertilizer benefiting both rice and fish.

Malagasy rice-fish farming is probably as old as rice cultivation itself and goes back to the royal era (Dabbadie and Mikolasek, 2017) but it is only after 1950, after common carp and tilapia were introduced in the country, that the use of improved practices started to be observed and spread (Lemasson, 1954, 1957). Unfortunately, in the absence of government’s subsidies, the process stopped and declined until FAO started to implement various projects from 1985 (Oswald *et al.*, 2016). The FAO approach was based on the privatization of fry production as well as on the promotion of the common carp stocking into the rice paddies (Dabbadie and Mikolasek, 2017; Oswald *et al.*, 2016). Since 2006, this FAO method was taken over, improved and implemented in 7 regions of Madagascar by the NGO APDRA to support smallholders and promote culture of carp in rice fields. Improvements include the rice plot construction according to the rearing stage, the use of fertilisation and affordable supplementary feeding in production, and the support to small-farmers hatcheries network. Rice plot construction consists of building a spawning pond of 3*3 m inside the parcel (Figure 1) for fry production and increasing side dikes and digging a fish refuge channel (Figure 2) for growing fish (APDRA, 2018a).

Figure 1: Spawing pond within rice plot for hatcheries.

Figure 2: Rice fish farming using fish refuge channel.

According to the Ministry of Fishery and Fish Resources (MRHP), there are currently 21 000 rice-fish farmers in operation throughout the country (MRHP, 2015), producing mainly Common carp with rice. Wild species involuntarily introduced in rice fields such as tilapia or *Carassius* sp. can contribute to secondary production of rice plots by up to five percent of the total harvested fish weight, providing an interesting additional income for farmers (APDRA, 2018b).

The production cycle depends on the objective of the farmer (fry production or fish growing-out), as well as market access and water availability. Generally, fry production period extends from September (end of August for the earliest) to December. However, to meet the late demand of fry for some fish growers, particularly on February, March or after floods, some fry producers try to postpone their spawning period at the beginning of the year. In most cases, fish growing-out is conducted during the rice production period (from November to June), but it may also continue after the rice harvest to get bigger fish. Fish yields change across regions, with natural productivity of the paddy and depending on the technical operations used by farmers (e.g. fertilization or fish feeding). For instance, in the highland, the average common carp yield is 200 to 300 kg/ha/year(APDRA, 2018b; Dabbadie and Mikolasek, 2017). According to AMPIANA (2019) , one of fish project working in the highland of Madagascar, the 2018 -2019 breeding campaign allowed a production of 1 150 000 fry with an average of 5 000 fry/hatchery.

Production data on integrated rice-fish production are still lacking but a study conducted in 2016-2018 showed that the stocking of carp in rice field enables the rice yield to increase by 19 percent to 31 percent if climate conditions are favourable (Mortillaro, Raminoharisoa and Randriamihanta, 2018).

Beside this traditional rice-fish farming system, another integrated practice has been experimented by APDRA with fish farmers on the east coast of Madagascar. Instead of stocking fish in rice fields, it consists in planting rice in fish ponds, as already practised in West Africa (Keita, 2019). During the 2015-2016 rice campaign, 82 percent of the fish farmers supported by APDRA harvested rice in their ponds, in addition to 765 kg fish/ha. According to APDRA (2017), the success of the system requires a good water management and good choice of rice variety.

3. Tanjona integrated crop-fish farming

Tanjona system is a new kind of integrated aquaculture system that emerged recently in the floodplains surrounding Antananarivo, the capital of Madagascar. The term Tanjona refers locally to a large dyke built in the middle of the floodplain (Figure 3), which serves as an emerged land plot that can be used for various crops during the rainy season, or for fruit orchards (in particular orange trees) throughout the year. Tanjona are not recent, as they were already mentioned in 1962 (Kiener, 1962). However, it is only recently, since 2000, that fish farming has been integrated in the system by connecting several dykes to each other, in order to delimit an enclosed water body inside, which can be used as a pond. While fish farmers were initially stocking wild fish in their ponds by trapping them during the flooding season, some progressively intensified their system by purchasing fry and feeding them.

Figure 3: Tanjona system in Fenoarivo, Madagascar.

A study conducted in Fenoarivo, a suburb locality where Tanjona systems are widespread, allowed to identify 27 integrated fish farmers (Mortillaro *et al.*, 2017). Two types of fish farming practices have been identified. The first type consists in practising fish farming in ponds and crops/orchards on dykes. With a production cycle of 6 to 12 months, the average fish yield is between 0.7 and 1.3 tonnes/ha.

The second type of Tanjona consists in an integrated rice-fish farming in the flooded part of the system combined with crops/orchards on dykes. The fish cycle is shorter (6 to 9 months) and the average fish yield observed in this system is between 0.3 and 1 tonne/ha.

Generally, fish are raised in polyculture and are fed on crops residues. Zebu waste is exclusively destined for fertilization of rice and vegetable fields, not for fish ponds. However, duck are sometimes introduced in the system after the crop harvest, to feed on plant residues and fertilize the water. The

Tanjona system provides essential financial resource for households, from 3 to 26 percent of additional income.

4. Livestock fish farming

By combining livestock such as cattle, pig or poultry with fish, animal excreta and waste food serve to stimulate water productivity, natural feed production and fish growth, as well as delivering other symbiotic benefits for both animals (Barash, Plavnik and Moav, 1982).

In Madagascar, integrated livestock-fish was first tested and carried out by FAO in the 1960s (Muir, 1981). Given its importance in Madagascar rural areas, it is common to see cattle used to provide manure to fertilize ponds or rice fields, even though it is not its sole purpose. It can also be used for labour and fish ponds construction. Some farmers also practice duck-fish farming to maximize the use and productivity of their water bodies, benefit from synergies and recycle nutrients. In 2016, 32 percent of the pond fish farmers supported by APDRA on the East coast of Madagascar had at least one livestock in their aquaculture system, and for 18 percent it was a poultry farm (chicken, duck, or goose) (APDRA, 2017).

On the other hand, some fish farmers with access to intensive farm wastes like pork or poultry manures have been able to significantly increase their fish production by transforming animal waste into other sources of animal protein for fish. One such example is a farmer using poultry litter to produce maggots serving as fish feed. With this method, it is possible to obtain 9 tonnes/ha of fish for a 15 months production cycle (Loharano Andriantafita, personal communication, 2017).

Unlike other countries, in Madagascar, the livestock farm is seldom located nearby or over the pond to facilitate the collection of manure and waste, because of the distance between the farmer's house and the fish ponds, which are often located in the lowlands. Organic fertilizers are also frequently used for other farm production than fish.

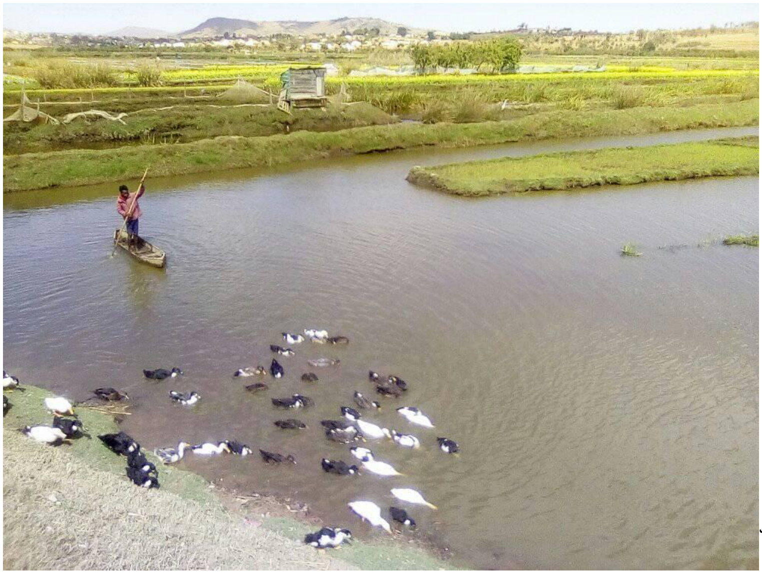

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Figure 4: Duck-cum-fish farming in pond in Vatomandry, Madagascar.

5. Advantage of integrated aquaculture

The main benefit of integrated fish farming is the synergies between livestock, crops and fish. The first one is related to the nutrients transfer between them. Indeed, fertilizers from livestock are reused by fish and crops for their growth. Fish in turn fertilize water with their excrements and improve the availability of some nutrients like nitrogen and phosphorus through bioturbation (Mortillaro, Raminoharisoa and Randriamihanta, 2018). Conversely, crop residues are used to feed directly or indirectly livestock and fish. Other benefits include the reduction in pest occurrence when fish eat crop pest. The main consequence of this recycling and synergies is the reduction of production costs for farmers.

Integrated aquaculture allow farmers to significantly improve their living conditions. Food is more readily accessible and available, and household incomes benefit from the sale of additional farm products. For example, fish farming contributes to 2 to 11 percent of the gross added value of rice fish farmer households (Randrianandrasana, 2017) and 3 to 26 percent of the gross added value of Tanjona farmer households (Mihaja Rakotoarinoro, personal communication, 2017). The additional income can improve family life, social activities, child wellbeing or education, or be used for investing in other activities or farm expansion.

6. Constraints of integrated aquaculture

In Madagascar, land availability is a major problem for many small-scale farmers. Indeed, integrated aquaculture requires access to favourable land. Favourable refers to water, its accessibility and the ability of the parcel to retain water for a long time without being exposed to natural hazard such as flood or drought. Unfortunately, the majority of these parcels belong to wealthy families. As a result, smallholders tend to use plots that are more vulnerable to climatic hazards (especially flood) and their land productivity is lowered.

Another issue is land ownership. In connection with their social status, the most common way for smallholders to have access to land is through renting or sharecropping. Five percent of the Malagasy rice fields are concerned by these methods (Burnod *et al.*, 2014), which is problematic as it may prevent farmers from investing into pond or rice-fish plots construction and/or expansion.

Another constraint relates to climate changes and hazards. In some cases, early or late beginning of the rainy season disturbs the cycle of production and creates a financial risk for farmers. In other cases, flood can result in fish escapees, crops destruction or dikes crumbling. For livestock, especially cattle, climate change can also induce a whole range of issues, especially with regards to new diseases.

Integration implies the diversification of activities, but it is not always easy for farmers to manage a new production that requires more investment in terms of finance, farm inputs and labour. With aquaculture, the main expense after construction is the fry purchase for stocking, which coincide with the lean season from September to January, when food shortage occur and school expenses are needed.

Last but not the least, theft is a constraint identified by many farmers, especially those producing fry as the loss of a common carp breeder is a big financial loss. Plots surveillance and monitoring is only possible if the house is not too far.

7. Prospects

Integrated Aquaculture-Agriculture has proven to be successful in many of the most advanced aquaculture countries such as in Asia (De Silva and Davy, 2010) thanks to its resilience. Although local studies have also shown its importance in Malagasy farms, its contribution is not yet fully perceived at the government and policymakers' level. Adoption and operationalization of development strategies that consider the economic and social benefits and constraints of integrated aquaculture, especially for small-scale farms and households, should be developed.

Current production yields are still quite low and very heterogeneous compared to other countries. This will require further research and support for the development of a more appropriate technical model for Madagascar, which takes into account the socio-agro-climatic constraints of the different regions.

Finally, a study of the evolution of integrated aquaculture-agriculture farming systems should be conducted in order to understand fish farming appropriation in the system, its impact on households, communities, farming systems and potential risks related to the system intensification.

8. Conclusion

The integration of aquaculture with agriculture and/or livestock is a very relevant activity for farmers in Madagascar, who generally have very limited inputs. Thanks to the synergetic effects of the integration, households can intensify and diversify their production in order to increase their incomes. But efforts should still be made for its mainstreaming at national level, by taking into account the socio-agro-economic disparities between regions.

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