Co-design ecologically intensive fish farming systems using agroecology and ecosystem services

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1 Introduction

The last few decades have shown high growth in global fish farming, whose quantity of production now equals that of fisheries(FAO, 2014). This change is associated with varying degrees of intensification of fish farming among countries. Therefore, many conflicts arise, and the place of fish farming is regularly discussed within regions, both as an opportunity and a risk. Therefore, it is necessary to reconsider the development of fish farming in the context of a growing human population on a planet with limited resources, but also in relation to local issues. Our study aimed to adapt to aquaculture, the concept of ecologically intensive agriculture (Griffon, 2013): use of ecological processes and functions to control pests, reduce pollution, make an efficient use of resources and improve services provided by ecosystems. This approach offers options to re-design aquaculture systems using biophysical and social mechanisms.

2 Materials and Methods

We defined the ecological intensification of aquaculture as a process that considers agroecological principles as defined by Altieri (1995), ecosystemic services supplied by the aquaculture ecosystem (MEA, 2005), and issues facing different types of aquaculture worldwide. The objective is not to propose a pre-existing model for implementing ecological intensification, but to identify a variety of possible pathways and describe driving factors, mainly environmental and technico-economic, but also those related to issues in the coordination and governance. In a first step, we built an expended framework to define the aquaculture ecosystem combining various ecosystem and territorial levels (Fig. 1). Then, we performed biophysical and ecological assessments (in particular, Life Cycle Assessment and Emergy Accounting (Wilfart *et al*., 2013)) coupled with the analysis of the regional stakeholders (fish farming, value chain and administration) perceptions of ecosystem services. Then, we used participatory approach at various stages of our work, in particular, to co-construct with stakeholders various scenarios involving new practices of ecological intensification and performed experiments with the selected practices. The approach is presented in Fig.1. We implemented this approach within six regions selected to cover a variety of aquaculture production systems (from extensive polyculture to monoculture activities in ponds or in recirculating water systems), ecosystems and socio- economic contexts in France, Brazil and Indonesia.

3 Results – Discussion

The project generated different levels of results. We first defined an ecologically intensive aqua-ecosystem, based on the flows of inputs, the variety of services provided and the different ecosystem involved (Fig. 2). We identified seven objectives to guide the adoption and the implementation of ecological intensification combining technical, environmental and social considerations:

1- Minimize dependence on external resource
2- Increase performance of aquaculture production systems and product quality
3- Improve robustness, flexibility, and resilience of systems via integration and functional complementarity
4- Diversify market-oriented ecosystem services of aquaculture systems
5- Promote recognition of services and better use of skills and know-how
6- Improve territorial integration of aquaculture systems by promoting production of non-market ecosystem services
7- Adapt mechanisms and instruments of territorial governance and help stakeholders participate

Then, we proposed a set of indicators to monitor the application and effects of ecological intensification in aquaculture.

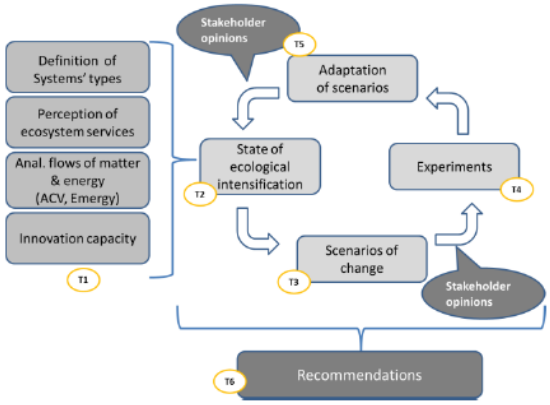

Fig. 1. Approach to co-design ecologically intensive aquaculture

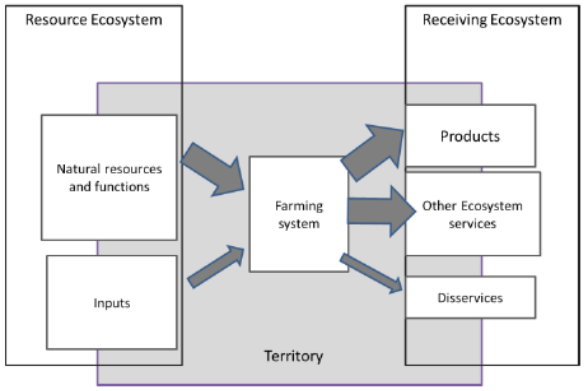

Fig. 2. Framework for ecologically intensive aqua-ecosystem

Different profiles of fish farmers were defined based on their ability to adopt the concept and on the way they apply it: only modifying input/output of the farming system, using the ecosystem services concepts to redefine the goals of their farming system, or to redesign the farming system. Regardless of the situation, adoption of the concept involves concerted efforts that depend on conditions for adopting innovations but also processes of collective engagement. Through learning processes during the various interactions with the stakeholders, the project also helped to modify the perception of the roles of aquaculture at the territorial level.

At the site level, experiments showed the environmental and economic potential of practices based on nutrient recycling, the association of fish and/or plant species, and new production systems were proposed. In Indonesia, a monoculture of panga (*Pangasianodon hypophthalmus*) was changed into a polyculture associating, a cage of panga, a floating plant (*Lemna minor*) and a high value herbivorous species (*Osphronemus goramy*). In France, the reuse of nutrients from outlet of intensive farming of salmon (*Salmosalar*) or carp (*Cyprinuscarpio*) was proposed for macrophytes co-production and for the creation of remediation spaces as a support for biodiversity. In Brazil, the concept of ecological intensification based on ecological services, leaded to propose new practices in pond effluent management and helped to conduct negotiations with territories managers for the sustainability of the activity.

4 Conclusions

The approach developed in this project, offers new perspectives to reconsider fish farming development, taking account its ecological and territorial integration. The generic characteristic of the approach provides a broad potentiality of application for various terrestrial systems. The approach and main conclusions of the project were synthetized in a guide for ecological intensification of fish farming (Aubin *et al*., 2014).

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