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Adoption of recirculating aquaculture systems in large pangasius farms: A choice experiment

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ABSTRACT

In response to increasing concerns about sustainable production, a growing number of European customers expect seafood products to be certified, e.g. by ASC certification. A possible answer to achieve environmental sustainability of Vietnamese pangasius farming is to apply recirculating aquaculture systems (RASs) at the farm. However, RAS requires relatively high initial investments and therefore its adoption depends largely on the economic feasibility in the Vietnamese farming context. The latter includes not only economic factors but also socio-demographic characteristics of the farmers.This study uses a choice experiment to measure farmers' preferences for RAS in pangasius production in Vietnam.

Findings show that the probability of adopting RAS is positively associated with expected higher yields and ASC certification with a price premium, whereas it is negatively associated with the initial investment. Location of a farm is also important, i.e. farmers in saltwater intrusion areas are more likely to implement RAS compared to those in freshwater areas. Other variables significantly associated with the probability of adopting RAS are age, education, gender, and household income. The overall probability of adopting RAS was low; the main constraints for adoption of RAS were farmers' uncertainty about the performance of RAS, lack of access to finance and lack of certainty about receiving the ASC price premium.

To stimulate the adoption of RAS, we recommend that policy makers target farmers with farms located in saltwater intrusion areas. We further recommend policies that link access to credit with investments in sustainability, and the establishment of pioneer RAS farms as a way to disseminate information about RAS and reduce farmers' uncertainty. Lastly, we recommend that retailers guarantee price premiums for ASC-certified pangasius.

Statement of relevance: Adoption of recirculating aquaculture systems is considered to be an important step to achieve compliance with sustainability certifications and disease control in pangasius farming. As a result, retailers and buyers in the EU can find pangasius products from environmentally sustainable and socially equitable production systems.

1. Introduction

Pangasius has become one of the most important export products of Vietnam. In 2013, exports of pangasius were valued around 1.5 billion USD; 24% of exports were to EU markets (Globefish 2013). In recent years, the sustainability of pangasius production has been increasingly questioned due to disease outbreaks (Phan et al., 2009; Le and Cheong, 2010), water pollution (Bosma et al., 2009; Anh et al., 2010a, 2010b) and antibiotic pollution from the discharge of untreated effluents into surrounding aquatic ecosystems (Rico and Van den Brink, 2014; Andrieu et al., 2015). Furthermore, retailers and buyers in the EU increasingly demand pangasius products from environmentally sustainable and socially equitable production systems, such as those with Aquaculture Stewardship Council (ASC) certification (Bush and Duijf, 2011; Little et al., 2012; Halls and Johns, 2013).

To mitigate sustainability concerns and to keep up with the increasing demand for ASC-certified pangasius, water purification technologies such as re-use and recycling of waste materials or the treatment of waste streams could be applied to reduce water pollution from pangasius farming (Anh et al., 2010a, 2010b). Recirculating aquaculture systems (RAS) were suggested as a potential solution to reduce waste discharge and to improve water quality in fish ponds as a response to environmental regulations (Martins et al., 2010).

Traditional pangasius farms usually operate one or several 3 to 5 m deep fish pond(s) with a sluice gate, and a feed storage. In the past, the majority of the farmers applied chlorine, lime, benzalkonium chloride and salt for water purification. Stocking densities vary from 5 to 31 fish/m3, depending on the size, availability of fingerlings and the financial capacity of farmers to purchase feedstock (Phan et al., 2009). More recently, most pangasius farmers use extruded pellets, except

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for a few small farms in traditional pangasius areas, such as An Giang, where extruded pellets are used together with farm-made feed. Most farms use river water in the fish ponds and discharge waste water directly into channels leading to the Mekong River. Water exchange is done using pumping or gravity from the tides (Ngoc et al., 2016).

The application of RAS in pangasius farms requires additional investment in a moving bed bio-filter, filter media, septic tank, pumps and pipes for water movement and aeration (Ngoc et al., 2016). In aquaculture, several RAS designs can be used, varying from an indoor, high-tech installation, for example, in European eel farming, to an in-pond configuration with a nitrification reactor and some devices for sludge separation. The current study focuses on the latter in-pond configuration. In this system, RAS separates solids from the bio-filter into septic tanks, thereby improving the water quality inside the ponds and reducing effluent discharge, while supplying additional oxygen for the fish. The airlift pump aims to get the water circulating in the pond that keeps solids moving towards a solids storage zone below the bio-filter which is suspended in the central part of the pond area. The solids are then pumped to a separate septic tank for denitrification process. Stocking densities are 76 fish/m3 and only extruded pellets are used with RAS (Nhut et al., 2013). Potential advantages are reduced disease infections and use of less antibiotics and chemicals (Gutierrez-Wing and Malone, 2006). However, the recirculation leads to high energy consumption either in the form of electricity or fuel for circulating in-pond water (d'Orbcastel et al., 2009).

RAS has been successfully implemented in many countries in Europe for different fish species, such as salmon in France, sea bass in the UK and trout in Denmark (see Martins et al. (2010) for a review and Badiola et al. (2012)) and also for low-value fishes such as tilapia in North America (Bunting et al., 2005) and African catfish in The Netherlands (Eding and Kamstra, 2002). As a response to sustainability concerns, the Vietnamese government wishes to stimulate ASC certification and compliance, in which RAS can play an important role. Recently, RAS has been implemented in a farm-scale pilot project for Vietnamese pangasius production (Nhut et al., 2015). Based on the perceptions of farmers, Ngoc et al. (2016) showed that farmers from large farms (greater than or equal to 3 ha) are generally positive about the expected economic performance of RAS. However, the adoption of RAS faces some constraints. Initial investment costs for RAS are relatively high (Ngoc et al., 2016). Furthermore, future yields, prices and operating costs for RAS are still fairly uncertain. This uncertainty combined with the high initial investment costs means that the economic feasibility is also uncertain and this may constrain the adoption of these modern production systems (Ngoc et al., 2016). To the best of the authors' knowledge, no previous studies have evaluated the willingness of farmers to adopt RAS or explored the factors that might influence this willingness.

The objective of this paper is to investigate the key determinants influencing the adoption of RAS by Vietnamese pangasius farmers. Given the high initial investment, we focus on large farms as these are more likely to adopt RAS due to their relative cost advantage (Pannell et al., 2006). In Vietnamese aquaculture, farms greater than or equal to 3 ha are considered as large farms. We defined key decision attributes and analysed decisions using a choice experiment. We expect the outcomes of this paper to provide useful insights to policy makers, which can be used to design policies and strategies that provide incentives for RAS adoption. The outcomes are relevant to policy makers from the Directorate of Fisheries, Ministry of Agriculture and Rural Development, and Local Aquaculture Departments in Vietnam, and to retailers and buyers in the EU.

This paper proceeds with the conceptual framework in Section 2. Section 3 presents the data collection, design of the choice experiment and the empirical model. This is followed by the presentation of results and discussion in Section 4. Conclusions and policy implications are in Section 5.

2. Conceptual framework

This paper is based on the expected utility theory, which postulates that within a set of choices, an investor will opt for the choice that maximizes her or his own expected utility (Fishburn, 1970). Expected utility is generally regarded as a function of profitability, implying that the investor's goal is to maximize utility by choosing the investment that offers the highest net profitability. Net Present Value (NPV) is the most complete and widely used investment appraisal method to assess profitability of an investment (Kay et al., 2012). The decision to invest is made when the expected present value of the investment cash inflows exceeds the investment cash outflows, i.e. the NPV is positive. NPV is defined by Kay et al. (2012) as:

$$NPV = -INV + \sum_{t=1}^{T} \frac{NCF_t}{(1+i)^t} + \frac{V_T}{(1+i)^T} \tag{1}$$

where *INV* is the initial investment, *NCF* is the annual net cash flow, which equals annual cash inflow (i.e. annual revenues) minus annual operating cash expenses, *V* is the terminal value, *i* is the discount rate and *T* is the lifetime of the investment. Discount rates contain three components: inflation, opportunity costs of capital and a premium for the level of risk embodied in the investment (Kay et al., 2012). We regard the NPV parameters in (1) as crucial for adoption decisions, and hence they form the key attributes in the conceptual framework of the choice experiment. The relevance of the NPV attributes for adoption decisions is supported by literature. For instance, Pannell et al. (2006) concluded in an extensive review on adoption decisions in agriculture that a higher *initial investment* negatively associates with the likelihood of adoption. With regard to the annual net cash flows, the literature shows positive associations between the likelihood of adoption and future *yields*, output *prices* (Pannell et al., 2006) and a *price premium* for environmentally certified products (Aguilar and Vlosky, 2007; Espinosa-Goded et al., 2010). With regard to the discount rate, Pannell et al. (2006) also confirmed that innovations subject to much *uncertainty* (i.e. reflected in a relatively high discount factor) are less likely to be adopted.

The literature provides evidence that socio-economic variables, including farmer demographics and farm characteristics, can also affect the NPV in Eq. (1). A number of variables can affect net cash flows, including *farm size*, *farm location* and *extension services*. Regarding *farm size*, larger farms have more potential to achieve economies of scale (Pannell et al., 2006; Gebrezgabher et al., 2015). As a result, larger farms tend to achieve a lower long run average cost than smaller farms. Likewise, *farm locations*, which capture regional differences in environmental conditions and infrastructure, are expected to influence expenses and returns generated from an investment (Khanna, 2001). Furthermore, the availability of information provided by private or public *extension services* enhances the technical performance of innovations, which has a direct impact on the net cash flows (Oude Lansink et al., 2003; Pannell et al., 2006).

The discount rate in Eq. (1) can also be affected by socioeconomic variables, including *credit accessibility*, *education*, learning effects from n*eighbours*, *household income* and *gender*. *Credit accessibility* refers to the ease or difficulty in acquiring credit, which will affect the opportunity costs of capital (Ismael, 2013). With regard to *education*, Knight et al. (2003); Marra et al. (2003) and Prokopy et al. (2008) concluded that more educated farmers are better able to access and understand new information, likely reducing the risk associated with the adoption of a technological innovation. Similarly, learning effects from n*eighbours* may eliminate the riskiness related to the innovation, when the neighbours have sufficient experience to make adoption profitable (Mercer, 2004). Additionally, the level of *household income* may have a risk-