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Mangrove forests and aquaculture in the Mekong river delta

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ABSTRACT

The mangrove area in Viet Nam is dramatically decreasing in the last decades. Since 1995, mangrove forests in south Viet Nam are allotted and contracted to households for protection, management and logging. Under this policy, households are allowed to convert 20–40% of the allotted forests into other uses, mainly shrimp farming. Most households develop mixed shrimp-mangrove farming systems, in which shrimp ponds are mixed with mangrove forest. With the poor enforcement of the forest assignment policy, however, the mangrove forest is over-extracted as farmers are converting more than the allowed level for larger water surface areas for shrimp farming and higher returns. In this study, we examine the impacts of mangrove coverage of mixed mangrove-shrimp ponds using the production and profit functions. Our analyses show that mangrove density has no impacts on shrimp farming. However, mangrove coverage affects productivity and profit of shrimp farming. The optimal mangrove coverage for shrimp farming is found to be approximately 60%. This implies that maintaining the level of mangrove coverage of 60% does not only to comply with the policy, but also bring about the highest level of output and profit for shrimp farmers.

1. Introduction

Mangroves are highly productive in maintaining a wide variety of flora and fauna species and supporting the coastal food chains. With the emergence of climate change problems, the ecosystem services of mangrove become more important. Mangroves play a crucial role in protecting coastal areas, and adapting to harsh environmental conditions. Mangroves serve as natural barriers to storm, shoreline erosion and sea level rise. Mangrove forests, with their physical structure and characteristics, lessen the strength of wind and the height of swell waves, bind and build soils, and as a result, reduce many threats associated with storms or hurricanes (McIvor et al., 2012). Mangroves' wide root and dense leaves reduce the effects of tidal and tsunami surge (Hiraishi and Harada, 2003). Mangroves also play an important role in carbon sequestration (Kristensen et al., 2008). Because of its capability to protect shorelines and riverbanks, mangrove forests are considered a good mitigation for sea level rise and provide an environment friendly and aesthetically pleasing protection (Black and Mead, 2001; Gómez-Pina et al., 2002; Khalil, 2008; Linares, 2012). In addition, mangroves have important services in maintaining biodiversity and purifying water (Alongi, 2008; Sathirathai and Barbier, 2001). A large number of studies have demonstrated the role of mangrove forests in reducing disaster risk and valued the ecological functions of mangrove forests using various methods (Salem and Mercer, 2012).

Mangrove forests also provide an important source of livelihood. As reviewed by Barbier (1994, 2007), mangrove forests provide not only indirect uses, including air pollution reduction, nutrient cycling, and watershed protection, but also direct uses including timber products, food, and recreation, contributing a significant value to households' livelihoods in surrounding communities. However, mangrove forests are known to be over-extracted by local users (Giri et al., 2011).

In Vietnam, the area of mangrove forests has declined dramatically during the last century. In the early 1940s, Vietnam had more than 400,000 ha (ha) of mangrove forest (Vietnam Environment Protection Agency [VEPA] 2005). In 2014, the mangrove forest area was reduced to 85,000 ha, with much lower biodiversity and biomass, and a very small percentage of that is natural forest (VNFOREST, 2015; Powell et al., 2011; Luu, 2000). Of the mangrove forest area in the Mekong River Delta (MRD), 161,277 ha had been converted for shrimp farming as well as other uses from 1953 to 1995 (Minh et al., 2001).

There are three types of mangrove forests in Vietnam: protection, special use, and production. Except for a few protected mangrove forests, others are managed by individual households. Since 1995, mangrove forests in South Vietnam have been allotted and contracted to households for protection, management, and logging. The households are paid an amount of money for managing the forests. In addition,

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logging is allowed, but subject to the approval of local authorities, and households can get part of the revenue from logging. Under this policy, households can also convert part (20–40%) of the allotted forests for agriculture, aquaculture, and housing. The main activity on land converted from forests is shrimp farming (Thu and Populus, 2007). Particularly, nearly 200,000 ha of mangrove areas have been lost over the past decades for shrimp farming (VEPA, 2005).

Although cutting mangrove forest beyond the allowed proportion is illegal, massive deforestation is ongoing due to poor enforcement. The lack of resources and expertise of the government have resulted in ineffective mangrove management, leading to the poor enforcement of regulations in mangrove management (Hawkins et al., 2010; VEPA, 2005).

The above-mention policy implies that mangrove coverage in mixed mangrove-shrimp farming systems should be 60–80%. However, previous studies found that 60–80% mangrove coverage is not the profit maximizing level (Tuan et al., 1992 cited by Binh et al., 1997; Binh et al. 1997; Minh et al., 2001; Bosma et al., 2014; Johnston et al., 2000). The average shrimp yield per hectare in Ben Tre province was 204 kg (kg) for ponds with 10% mangrove coverage and 324 kg for ponds with 40% coverage (Tuan et al., 1992 cited by Binh et al., 1997). Meanwhile, Binh et al. (1997) analyzed data from integrated shrimp ponds in Ngoc Hien District and found that ponds with mangrove coverage of 30–50% have the highest return. In a recent review, Bosma et al. (2014) also confirms the optimal mangrove coverage of 30–50%. Nevertheless, Tran (2005, cited by Bosma et al., 2014) found that farms with coverage less than 30% yield higher revenue in Ngoc Hien and Nam Can districts, Ca Mau province. These levels of mangrove coverage are lower than the current required level and applying them would result in the massive conversion of the mangrove forests allotted to households, leading to the loss of many ecosystem services to the community.

The policy of mangrove forest assignment, the poor enforcement of regulations related to mangrove management, and previous studies highlight the need for a proper examination of the impacts of mangrove coverage on shrimp farming. Although there are many studies on the impacts of mangroves on shrimp farming in Vietnam, only a few of them analyzed the issue from an economic perspective, i.e. estimating the production or profit function. In addition, these studies failed to control important variables, which may result in biased estimates. Binh et al. (1997) analyzed the impacts of mangrove coverage, density and age on integrated shrimp farms in Ngoc Hien district (Vietnam) using a simple linear production function without controlling important inputs. Similarly, Johnston et al. (2000) did not control for important inputs. Minh et al. (2001) focused on factors related to natural shrimp production (e.g., water depth, water area, harvesting technique, and exchanged water level) on production, but did not control for mangrove-related variables as well as important inputs. Omitting inputs of the shrimp production process may results in biased estimates of the production function.

In this study, we investigate the effects of mangrove coverage using the production and profit functions with data from a farm survey of the coastal areas in Vietnam's MRD in 2015. The rest of this paper is organized as follows. The next section discusses the role of mangroves in shrimp farming. We then provide the specification of the production and profit functions applied for this study, the estimation strategy as well as the study locations and data. Finally, we present and discuss the results.

2. Mangrove ecosystem services and shrimp farming

A mangrove-aquaculture farming system consists of mangrove forests and water surface. Households assigned with mangrove forest areas clear some parts of the forests into water surface for aquaculture. Depending on the water level, shrimp and other aquatic species can move from the water into the parts of forests and thus enjoy the shading and many benefits from mangrove. First, mangrove forests play a role in reducing the turbulences of climate conditions which can damage aquaculture production in coastal areas. Second, mangrove forests help decreasing the levels of pollutants, mitigate variation in salinity and turbidity (Larsson et al., 1994; Kautsky et al., 1997), reducing the flow of tidal water, and facilitating the deposition of sediments which may filter out and treat toxins. Finally, mangrove forests are also nursery grounds and habitat for many species that provide nutrients as feed inputs to shrimp farming (Nagelkerken et al., 2008; Hong and San, 1993). These services are important for mangrove-aquaculture farming system.

The substantiality of shrimp farming is supported by the ecological system as the source of feeds and clean water. Larsson et al. (1994) found that one ha of shrimp farm in Columbia requires 4.2 ha of mangroves to purify water and provide feed. Expansion of the water surface for shrimp leads to the deterioration of the water filtering capacity of surrounding mangroves, which subsequently self-pollutes the farm area (Rönnbäck, 1999). In addition, the role of mangrove forests in sustaining water quality is even more important in maintaining the environment for species that provide natural feed for shrimp (Menzel, 1991; Beveridge et al., 1997).

The natural food input production in mangrove forests, perhaps, is the most crucial role that mangroves play in aquaculture. The mangrove food web is mainly supported by the transformation of mangrove leaf litter into detritus and the presence of plankton, microphytobenthos, and epiphytic algae (Nagelkerken et al., 2008). Larsson et al. (1994) found that mangrove coverage of 25% provides about 70% of feed requirement. In addition, Gatune et al. (2012) proposes that mangrove leaf litter longevity could be a deterministic component of the nutrient supply of the ecological system.

Mangrove forests are also life-support systems in sustaining numerous marine species (Rönnbäck, 1999). A majority of marine species reside in the mangrove system at a stage of their life cycles (Nagelkerken et al., 2008; Beck et al., 2001). Molluscs, especially oyster and mussels, can use mangrove roots as living ground.

Mangrove forests play a crucial role in the natural production of wild seeds or fry in aquaculture. Shrimp seeds can enter aquaculture systems artificially or naturally via the intertidal zone (Rönnbäck, 1999). Converting mangrove areas to intensive shrimp ponds reduce the nursery ground as well as shrimp recruitment. This not only reduces shrimp yield in the mixed mangrove-shrimp ponds, e.g., 100–150 kg/ha/year in 2003 in comparison to 1300 kg/ha/year (Tran, 2005 cited by Bosma et al., 2014), but also to decrease the mangrove mollusk yield (Menzel, 1991). Apart from the diminishing productivity, farmers also bear a significant larvae cost due to the loss of natural recruitment of production stock.

Although mangroves purify water, they can also cause pollution. If the drainage system in shrimp ponds with mangrove cover is insufficient, ponds could become shallow because of sediment accumulation, leading to temperature fluctuation. Moreover, in narrow and long ponds, water exchange may be limited resulting in wastes and litter accumulation in the far end of the ponds (Tran, 2005 cited by Bosma et al., 2014). Other studies also found adverse effects of mangrove forests on aquaculture. Johnston et al. (2000) found that mangrove leaf litter affect the survival and growth of shrimp. In addition, different species of mangrove have different effects on aquatic organisms in ponds (Basak et al., 1998; Hai and Yakupitiyage, 2005). Dissolved oxygen is consumed significantly in the process of leaf litter decomposition, which result in reduced water and sediment quality, and reduced body weight of shrimp (Fitzgerald, 2000; Sukardjo, 2000). In this way, there is a decrease in the natural food production in aquatic ponds (Lee, 1999). Compounds from mangrove trees (i.e., tannic acid in *Rhizophora* leaves), also have negative effects on the survival and growth of aquatic organisms (Inoue et al., 1999 cited by Primavera, 2000). Besides, aquatic organisms are also damaged by other substances from mangroves trees such as root, bark, and stems (Madhu and