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Impact of shrimp aquaculture development on important ecosystems in India

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ABSTRACT

The rapid growth of aquaculture has raised the environmental concern about the conversion of ecologically important areas such as mangroves and agricultural lands. The study explored the impact of shrimp aquaculture on land use change in India's coastal wetlands using Landsat satellite data, geographical information system techniques and field verification. From 1988 to 2013, the area under aquaculture has grown by 879 %, which brought the tremendous changes in the coastal land use pattern. Mangrove and agriculture lands have been used for 5.04 % and 28.10 % of the aquaculture growth. Mudflats, scrublands, saltpan, and waterbodies have contributed to 51.65 %, 1.76 %, 1.73 % and 2.37 % of the aquaculture area expansion respectively. Mangrove areas have undergone severe changes due to gain and loss at different places. Environmental factors influenced the changes in mangroves, and the overall extent of mangrove has increased by 13.44 %. Construction activities and aquaculture have reduced the agricultural land by 3.52 % and 0.53 % respectively. The variation between the actual area under shrimp aquaculture and the Coastal Aquaculture Authority approved area indicate that the larger extent of shrimp farm operates without approval. Implementation of an intensive monitoring program for strict adherence to coastal aquaculture regulation laws will be helpful for the sustainability of coastal resources as well as aquaculture.

1. Introduction

Aquaculture is the world's fastest growing food production system at an annual rate of 8 % and contributes 44.1 % of world fish supply of 167.2 million tonnes (FAO, 2016). It also makes use of wastelands for poverty alleviation, economic development, and coastal livelihood upliftment, supports around 500 million people in developing countries directly or indirectly, through fisheries and aquaculture. (FAO, 2008). Global attention drawn on shrimp aquaculture was not only because of the economic success but also due to the environmental issues raised over the unregulated and unsustainable development. Adverse environmental impacts related to shrimp aquaculture have been widely reported (Primavera, 1997; PÁez-Osuna, 2001). In spite of the economic gain, shrimp aquaculture development has made the loss of mangroves and waterways (Thu and Populus, 2007). As mangrove forests are the most productive and biologically important ecosystems, the loss due to aquaculture is a key setback for the sustainability of aquaculture as a whole. Researchers have indicated that one-third of the mangrove forests worldwide have disappeared in the last 20 years, 35% was lost to aquaculture, which may reach 60 % by 2030 (Alongi, 2002; Simard et al., 2008). In addition to this, conversion of agricultural land into shrimp ponds and salinization of agricultural lands was yet another prominent issue in the context of developing countries where the aquaculture is rampant (Ahmed et al., 2010). Large-scale conversion of agricultural lands to shrimp farms has been reported in Thailand and Vietnam (Szuster et al., 2003). Studies have indicated that conversion of other land classes for aquaculture could lead to adverse ecological impacts and conflicts with other users (Pérez, 2003). Researchers have indicated that the discharge of saltwater from shrimp farms caused the salinization in adjoining rice and other agricultural lands (Dierberg and Kiattisimkul, 1996), leading to a reduction in agricultural production. Studies have indicated that the small-scale agricultural farmers who converted their land for aquaculture have abandoned them after short-term use due to the White Spot Syndrome Virus disease outbreak (Jayanthi, 2011). The impact of conversion of agricultural land to aquaculture will be adverse on small-scale shrimp farmers if the disease outbreak occurs in their farms as they are generally resource poor.

In India, shrimp farms started in the late 1980 s in response to international market demand, whereas Andhra Pradesh, West Bengal,

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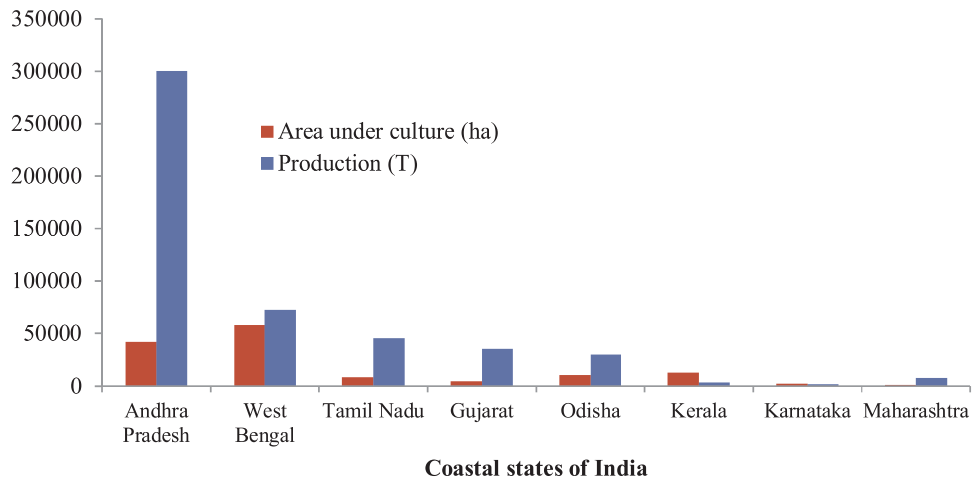

Fig. 1. Shrimp culture area and production in the coastal states of India.

Tamil Nadu, Gujarat, and Odisha are major shrimp producing states. Out of 1.2 million hectares of coastal salt-affected lands suitable for brackishwater aquaculture in India, 140656 ha was utilized, contributing about 24426.74 crores to the country total seafood in value, which accounts for 6.62 % of world aquaculture production (MPEDA, 2016). Fisheries and aquaculture are state subjects under Indian constitution, the entire inland aquaculture, and fisheries, marine fisheries up to 12 nautical miles from the shore comes under the state administration for the management. Each state has a full-fledged fisheries department for its development and management. Coastal Aquaculture Authority (CAA), Government of India is empowered to provide the licenses for shrimp aquaculture in the coastal regions of the country. Similarly, mangrove wetlands are also protected by the respective state forest departments. Like other shrimp growing countries, the expansion of aquaculture in India too has created a concern about its impact on the environment (Jayanthi et al., 2006). Studies have indicated that the shrimp culture was responsible for the overall degradation of mangroves in India's East Coast (Hein, 2000) and the conversion of fertile agricultural lands (Alagarswami, 1995). As there is no scientific evidence available on the quantification of the impact of aquaculture development on the wetlands and their surroundings, use of spatial tools is a better option to measure such changes.

Remote sensing (RS) applications have proliferated into almost every facet of development in the last three decades. Geographic Information System (GIS) facilitates efficient management and analysis of spatial data of different periods (Burrough and McDonnell, 1998). RS and GIS provide the techniques to detect changes in coastal systems under continuous environmental stress induced by the activities in or around them. Change dynamics of the land use can only reflect the impact of the interaction of human activities with the environment. We need to detect the changes of the significant classes of spatial data while rejecting 'unimportant' changes. Different techniques such as pre and post-classification comparison have been used in the spatial data change detection analysis (Coppin et al., 2004). Among the change detection methods, image differencing, principal component analysis and post-classification approach are the most commonly used methods and confirmed the better performance (Collins and woodcock, 1996; Lu et al., 2004; Tewkesbury et al., 2015).

Many researchers have studied the impact of aquaculture development on the land use changes of coastal wetlands using remote sensing and GIS, for example, Mekong delta, Red river delta, Xuan Thuy reserve area, Kien Giang of Vietnam (Tong et al., 2004; Béland et al., 2006; Thu and Populus, 2007; Seto and Fragkias, 2007; Nguyen et al., 2013); Mahakam delta of Indonesia (Rahman et al., 2013); Sinaloa wetlands of Mexico (Berlanga-Robles et al., 2011; Alonso-Pérez et al., 2003); Gulf of California arid lands (Alatorre et al., 2016) and Pernambuco coast of Brazil (Guimarães et al., 2010). Assessment of mangrove deforestation rate and its drivers in Southeast Asia indicated the reduction of 0.18% per year between 2000-2012, mainly due to aquaculture expansion (Richards and Friess, 2016). Aquaculture impacts assessment of India's coastal wetlands, such as Godavari delta of Andhra Pradesh, Vellor - Coleroon estuary of Tamil Nadu, Mahanadi delta of Odisha, Sundarbans of West Bengal (Giri et al., 2007; Rajitha et al., 2010; Jayanthi, 2011; Pattanaik and Prasad, 2011) indicated the absence of comprehensive national data at a particular time. A close perusal of the literature revealed that scarce information in bits and pieces are available, representing few wetlands of India with a different period, and also offer no information at a state level which could help the respective state governments to develop policy and conservation measures. Spatially explicit, detailed information for aquaculture developed states of India, consistently at a single point of time are required to direct and inform the management of ecosystems and also to plan for sustainable development of aquaculture. In this study, we have evaluated the land use changes due to aquaculture expansion on the coastal wetlands and their surroundings in the shrimp growing states of India.

2. Materials and Methods

2.1. Study area

The study focused on the impact of aquaculture on the land use of important coastal wetlands in major shrimp growing states of India, namely Andhra Pradesh, West Bengal, Tamil Nadu, Gujarat and Odisha covering an extent of 6291232 ha. The area under shrimp culture and state-wise shrimp production in 2015 (MPEDA, 2016) is given in Fig.1. India has different shrimp farming systems ranging from extensive to intensive systems with varying stocking density of 10 - 60 /m^2 and saline conditions from freshwater to seawater. *Penaeus monodon* and *Penaeus vannamei* are the shrimp species being cultured in India. The climate is tropical wet and hot with a temperature range between 18 °C and 48 °C. Rainfall occurs due to Southwest monsoon (June to September) in the coastal states studied except Tamil Nadu, which gets the rainfall from Northeast monsoon (October to December). The annual rainfall averages between 750–1500 mm across the region. Table 1 indicates the extent and geographic location of the study area, date of satellite image acquisition and the names of wetlands covered.

2.2. Data selection

Two-period satellite data, i.e., Landsat 7 Enhanced Thematic Mapper Plus (ETM +) of the year 2013 and Landsat 4 Thematic Mapper (TM) of the year 1988, with 30 m resolution were used in the study. The