Rajakumari S *et al*, International Journal of Advances in Agricultural Science and Technology,
Vol.6 Issue.7, July-2019, pg. 21-33
ISSN: 2348-1358
Impact Factor: 6.057
NAAS Rating: 3.77

Trajectory of Aquaculture Growth and Agriculture Risk with Predicted Scenario in the Western Bank of Hooghly Estuary using Remote Sensing and GIS – A Review

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Abstract

Aquaculture farming is at its boom in the last two decades. Most of the rivers and canals are banked with aquafarms globally with India as no exception. India ranks third in the world in aquaculture production. East coast indicates significant growth of aquaculture farms in the past few decades. The western bank of Hooghly estuary is one of the noted zones for aquaculture farming. This paper detailed the growth of aquafarms in the above mentioned coastal zone in the last few decades along with predicted scenarios in the next two decades. The impacts of increasing aquafarms in the inland, river banks and along the coast were also discussed in the paper. Temporal analysis and predictions were done using Remote sensing and GIS techniques along with CA-MARKOV land use/land cover prediction model.

Keywords: *Aquaculture Farms; Hooghly Estuary; Temporal analysis; prediction model*

1. Introduction

Growth of aquaculture activities is almost inevitable in the present global scenario owing to its high profit rates, demands and market facilities. Almost all major coastal aquatic environments are utilized or converted for this purpose. Though this conversion may lead to depletion of soil quality and ground water in course of time, the profitable livelihood of the activity has overtaken these negative impacts. India is no exception for this. The growth of aquaculture activities in India is rapid in the past few decades. Significant growth of aquafarms is noticed in the east coast especially in the Purba Medinipur district of West Bengal. The district is one of the pioneer (Maity Purna Chandra 2013) in prawn culture in India. This paper indicates the growth of aquafarms along the western banks of Hooghly estuary from 1972 to 2017. The paper also indicates the replacement rate of the traditional agriculture areas as aquafarms during this period. Attempts were made to predict the expected growth of the aquafarms and loss of agriculture lands in the next two decades using Remote Sensing, GIS and Prediction Model. Remote sensing with its panoptic, temporal nature and extensive spatial tools in GIS would aid in estimation of land use land cover change pattern (Jadab Chandra Halder 2013; Kaberi Samanta and Sugata Hazra 2012).

2. Study Area

The study area includes 9 coastal blocks of which 8 belong to Purba East Medinipur district of West Bengal and 1 block belongs to Baleshwar district of Odisha in the East coast of India. The total spatial extent of the study area is about 1435 km^2. The study area forms the western bank of Hooghly estuary as indicated in Figure 1.

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Figure 1: Study Area

3. Data and Method

The approach of the study involved three steps. Step 1 includes georeferencing of temporal satellite images using standard Ground Control Points (GCP) and interpretation of the features using standard interpretation techniques. Satellite images of different temporal years were used as the primary input for the study. The details of the satellite images used were given in Table 1. The next step includes importing of the interpreted layers as thematic data in GIS domain for analysis. This step involves spatial area calculation of all the land use features within the study area for different periods and also to extract the agriculture and aquaculture farms from the temporal layers for further analysis and study.

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Table 1: Temporal Satellite Data

Year	Data	Datum	Spatial Resolution (m)
1972	LANDSAT	UTM 45/WGS84	30
1997	LISS III	UTM 45/WGS84	23.5
2007	LISS III	UTM 45/WGS84	23.5
2012	LISS IV	UTM 45/WGS84	5.8
2017	LISS IV	UTM 45/WGS84	5.8

The final step of the study was to predict the status of the agriculture and aquaculture farms within the study area using prediction model. The prediction model used for the paper was Cellular Automation coupled with Markov model, also called as 'CA-MARKOV' analysis model.
Cellular Automation coupled with Markov model (CA-Markov) which is the most widely used approach to predict the spatial - temporal dynamics of land use/land cover (LULC) features. The model has two components, one is the determination of the temporal dynamics in the LULC features on pixel by pixel basis by Markov approach and the second component is the prediction of future dynamics i.e. both spatial and temporal dynamics of based on the set of rules and probabilities generated by the model in the first component. In this paper, land use of 2007 was given as the first component and land use of 2017 was given as the second component. The model predicted the temporal dynamics between the two components and creates auto generated set of rules and probabilities of conversion between 2007 and 2017 (i.e. for 10 years). In the prediction part of the model, the 2017 layer is given as the basic layer and the corresponding transition probabilities and areas auto created by the model were given as input for predicting the next 10/20 years scenario. In order to estimate the reliability and accuracy of the predicted data, error matrix analysis and Kappa statistics were performed. Error matrix analysis indicates the consistency percentage between the actual and predicted values for each of the land use/land cover classes considered, while kappa coefficient indicates the correctness and correlation of the actual and predicted features on pixel by pixel basis. The error matrix and kappa coefficient of correlation for the 2017 predicted data was about 91% and 94% respectively for the land use/land cover features indicated in the study area.
For better validation and accuracy test, the above method of prediction was executed for 2012. The predicted spatial statistics were compared with the actual data of 2012. The accuracy assessment indicates a 94% correlation.

4. Result and Discussion

During the past 2 decades there has been haphazard growth of aquaculture practice in the western banks of Hooghly estuary in the East coast. High economic benefits (Atanu Ojha and Abhisek Chakrabarty 2018) by exporting the yield and favorable brackish environment due to influx of saline water (Dipanwita Dutta et al., 2016) during high tide are the reasons for booming and shifting of agriculture to aquaculture in the study area. The total extent of the study area is about 1435 km^2, of which agriculture forms the primary activity occupying 59% of the total area. The other LULC features identified by the study were plantation, saltpans, tourist spots, sandy areas, mangroves, mudflats, aquafarms, built up areas including settlement areas/ industries/harbor/port, scrub lands, coastal dunes, rivers/canals/streams network, natural and manmade fresh water tanks and waterlogged areas. The changes in the spatial extent of agriculture lands and aquafarms were calculated out of the total LULC features of the study area. Figure 2 indicates both the actual dynamics of agriculture and aquafarms areas in the last 45 years (1972-2017) and also the results of the predicted scenario of these features in the next 2 decades.
The study indicated a gradual conversion of both the features from 1972 to 2012 as represented in Figure 2. But the rate of change in both the features shows rapid variation thereafter. The reason being the awareness of the people on the national and global market demand of the aquaculture products and also their higher annual yields (Atanu Ojha and Abhisek Chakrabarty 2018; Sahu et al., 2012) . The extrapolation of the above data indicated that the study area may be dominated with aquafarms than crop lands in the next 4 to 5 decades. Both the predicted and extrapolated

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scenarios will have adverse effect on the food crop production of the state, water networks lined with aquafarms and also on the coastal features such as mangroves and mudflats as indicated by the study.

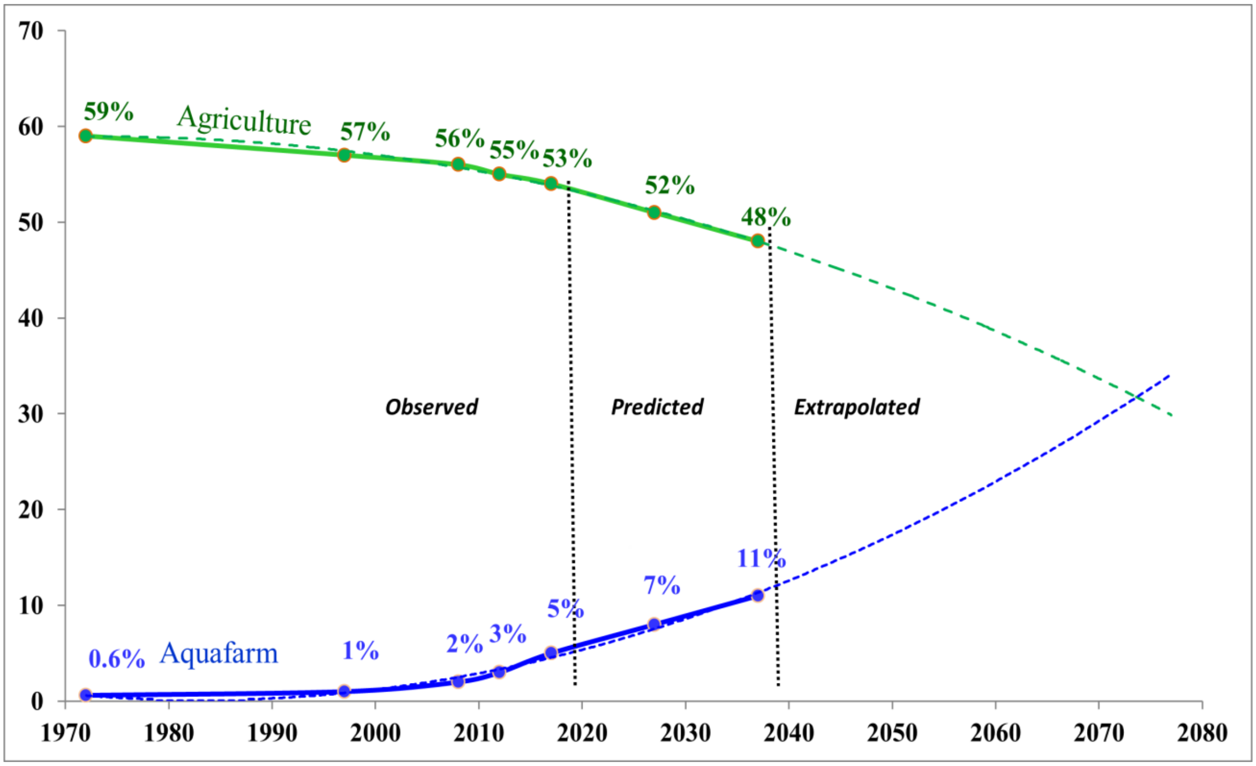

Figure 2: Scenarios of dynamics of agriculture and aquafarm areas expressed in %
(Actual, Predicted, Extrapolated)

Figure 3 indicates the spatial locations with significant growth of aquafarms at different time period. The study indicated a gradual growth of aquafarms in different locations from 1972 to 2017. The temporal analysis of the new aquafarms indicated that the major converted areas are along the banks of rivers and canals. Significant growth was found on the southern region of Rasalpur river in Deshapran block. This area has about 40% of the total aquafarms in the study area. Southern bank of Haldia river also indicated as a targeted area for aquafarms since 2017. Coastal areas of Ramnagar II, Contai I, Deshapran and Nandigram I were also noticed with aquafarms with gradual spatial expansions at different period of time. The coastal features under threat for aquafarm conversions are mostly mangroves and mudflats. This increasing trend of aquaculture has caused about 8% mangrove degradation.

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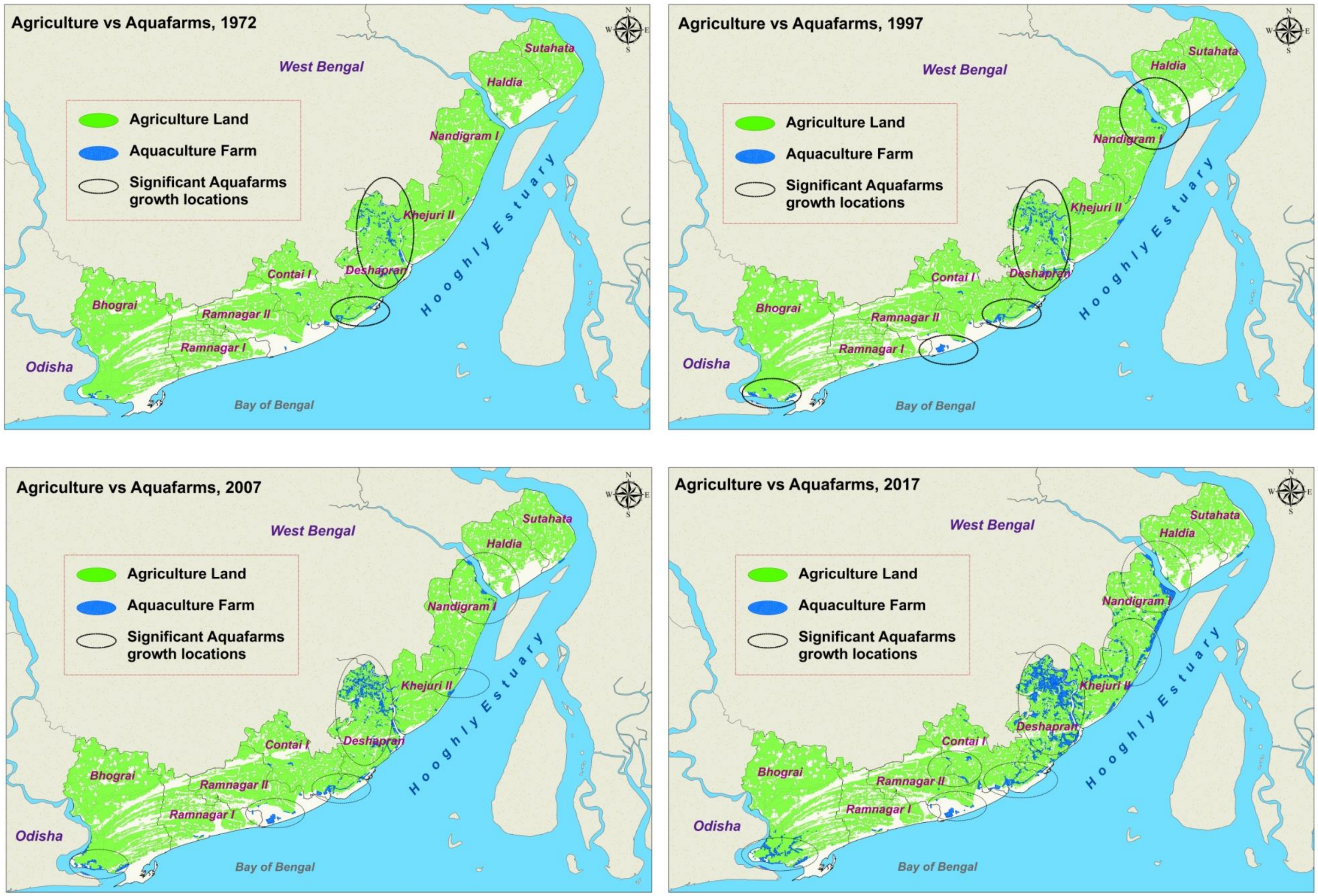

Figure 3: Spatial variations of agriculture and aquafarm areas in western bank of Hooghly estuary (*Temporal data*)

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4.1 Agriculture risk and Aquafarm growth

The growth of aquafarms are by conversion of various land features such as scrub lands, mangroves, mudflats, waste lands etc. However the percentage of crop lands utilized for aquafarms is comparatively higher.

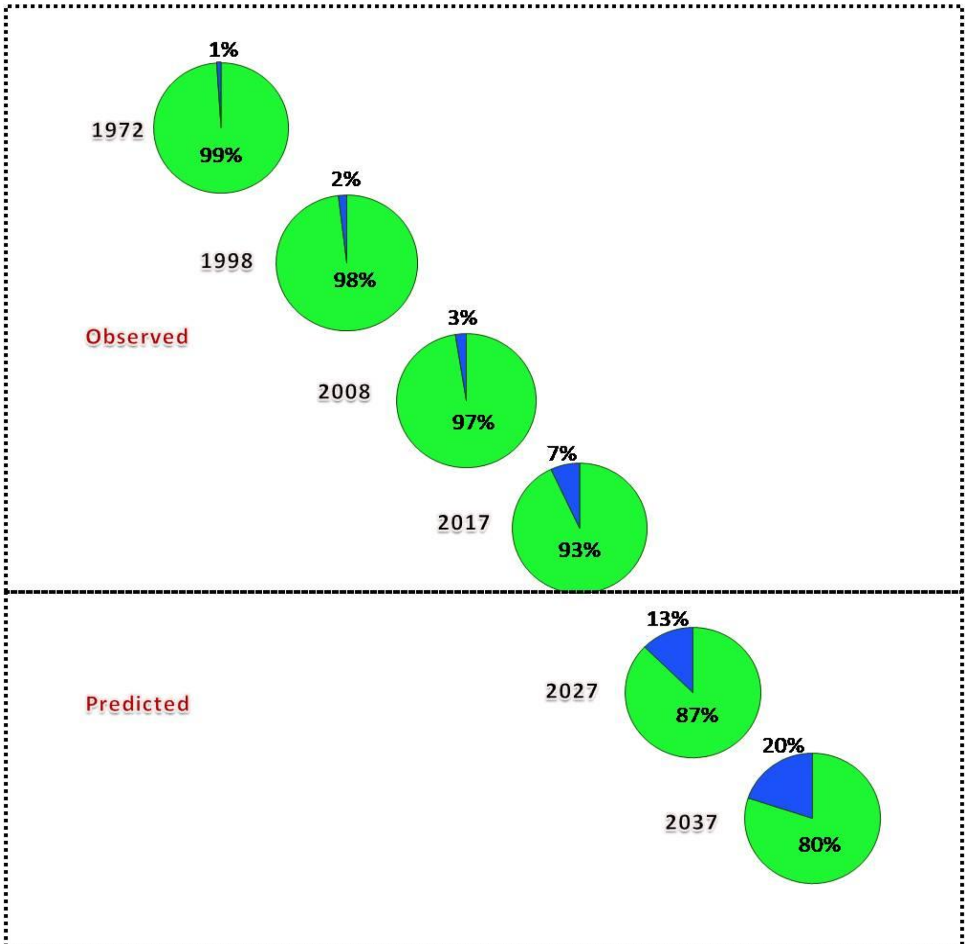

Figure 4: Conversion of agriculture lands to aquaculture farms

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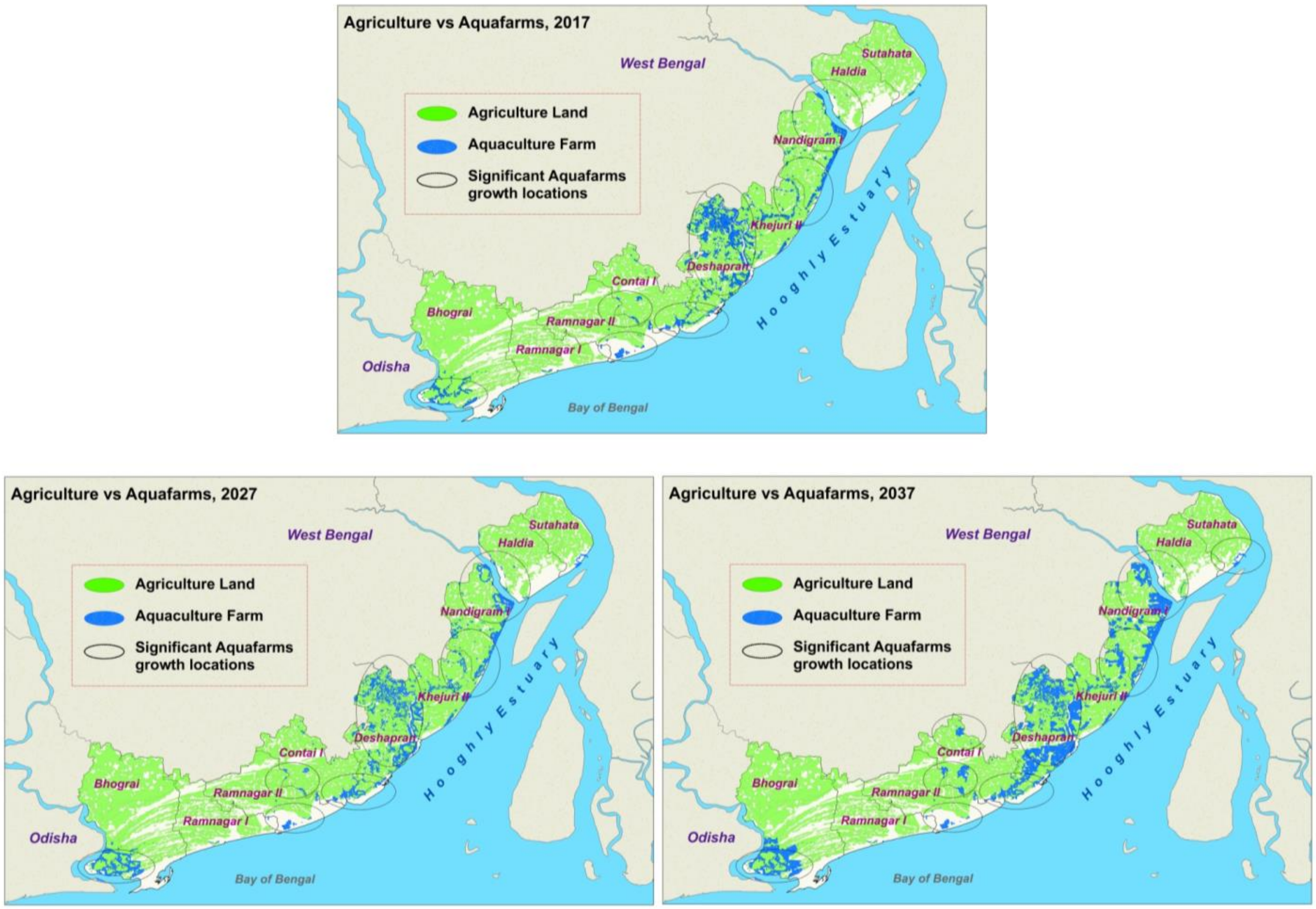

Figure 5: Predicted extent of agriculture lands and aquaculture farms (*Model data*)

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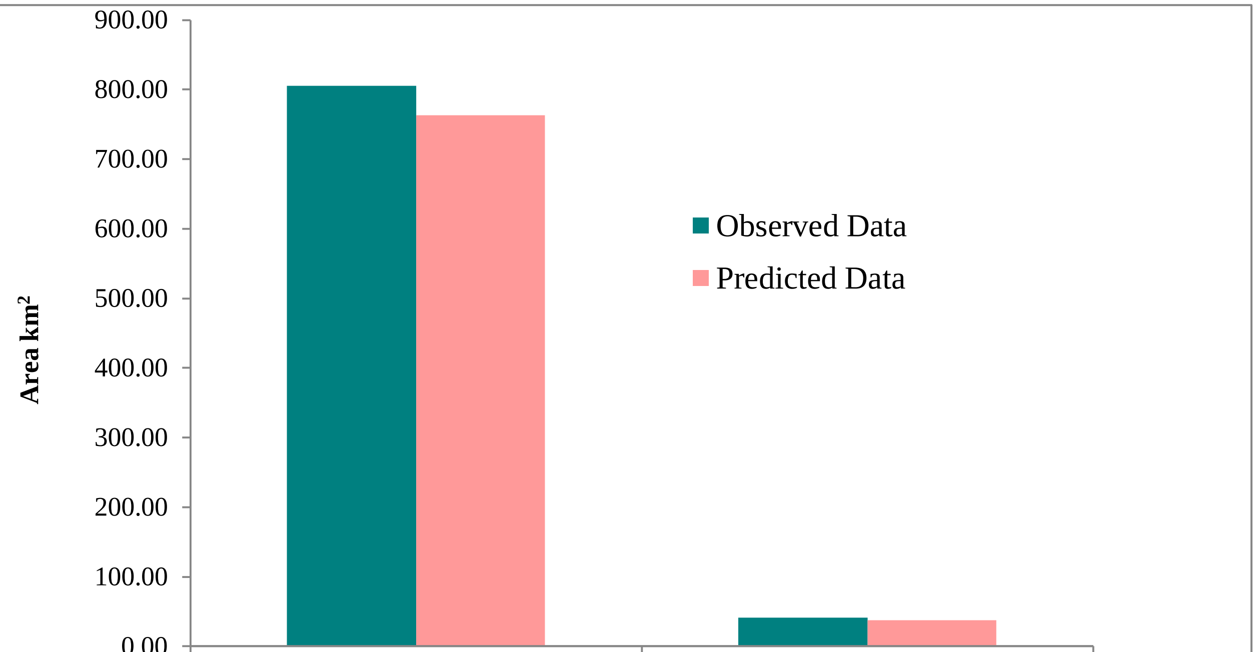
The reasons for the tremendous conversion is being lack of fresh water facility (Zakir Hossain 2009) for sustained cultivation, non suitability of soil for higher crop yields, as well as the ease of high profits from other economic activities of the area such as coastal tourism and saltpans motivated the local people to indulge in aquafarm practice that has competitive demand and high marketing value compared to food crops. Figure 4 indicated the conversion of agriculture lands to aquafarms. Higher investment cost for marginal yields has resulted in higher rate of conversion of traditional agriculture lands. As per the study, the rate of conversion of crop lands started with 1% in 1972 and grown upto 7% in 2017. The predicted scenario indicated a further increase in the conversion rate upto 20% in the next two decades as indicated in Figure 4. Livelihood sustainability and improvement with less effort is one of the main factors for this change.
The predicted spatial locations of aquafarms in 2027 and 2037 by CA-MARKOV model indicated both expansions of existing farms and also origination of new farms in new locations as shown in Figure 5.

4.2 Accuracy Assessment of Predicted Model

The prediction of the status of crop lands and aquafarms in the western banks of Hooghly estuary was carried out with CA-MARKOV model and the accuracy of the model was assessed using Error matrix and Kappa statistics which were explained in the earlier section of the paper. The correlation was found to be about 91% and 94% respectively.



	Agriculture (Sq km)	Aquafarm (Sq km)
Observed Data	805.50	40.86
Predicted Data	763.26	37.72

Figure 6: Accuracy Assessment of actual and predicted data-2012

To indicate the accuracy of the predicted data, the prediction was done for 2012 with the same transition and probability transitions rules generated by the model to predict 2027 and 2037. On contrary, the first land use layer given as input to the model is 2007 and the number of years indicated for prediction is 4. The statistics and spatial areas predicted by the model for 2012 are shown in Figures 6 and 7. The correlation assessment is about 94%.

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Figure 7: Spatial Extent of agriculture and aquafarms of 2012 (Actual and Predicted)

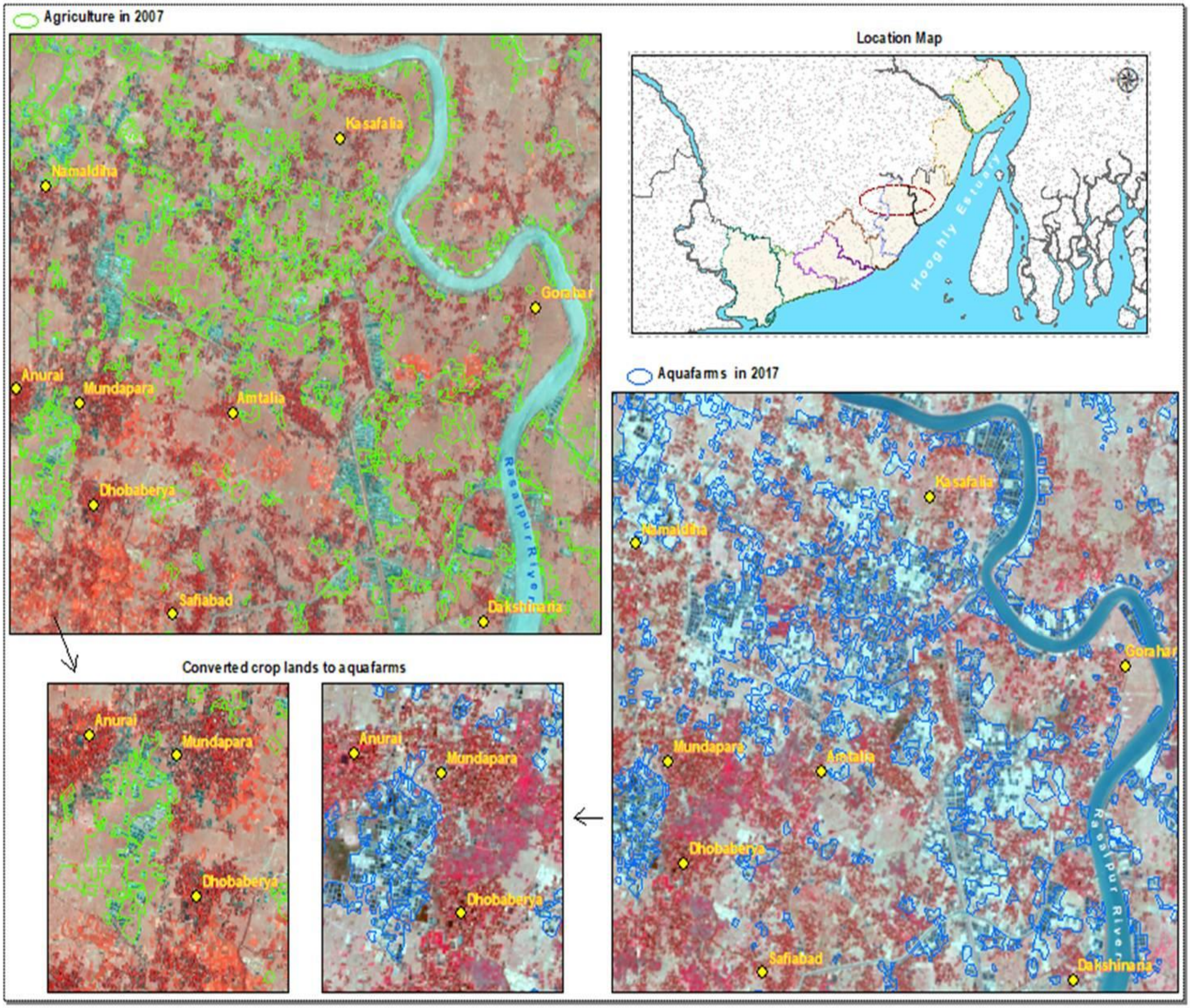

Figure 8: Conversion of agriculture lands to aquaculture farms near Mundapata, Deshapran block

4.3 Impacts of conversions

Conversion of land features are site specific as per the environment and suitability. Shifting of land use is mostly inevitable especially in the coastal areas due to availability of resources and its associated developments. But unproportionate growth, though indicate monetary benefits will result in environmental degradation. In course of time the area losses its native significance and showcase as coastal stretch under various threat. Legal regulations are

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imposed within a certain distance from the shore. But often the root cause for stress originates from inland and propagates towards the coast. In this study the uncontrolled growth of aquafarms may elevate the challenges to the coast in the near future. As indicated in Figure 9, though growth of aquafarms indicates a relatively less impact on inland areas, its impact on river waters and coastal areas are high. Both these factors along with its geographical location i.e. in the mouth of Hooghly estuary which is one of the most tide dominated coasts of India may impose adverse effects. As depicted in Table 2, the study indicated high rate of stress along the coastal areas also in the future.

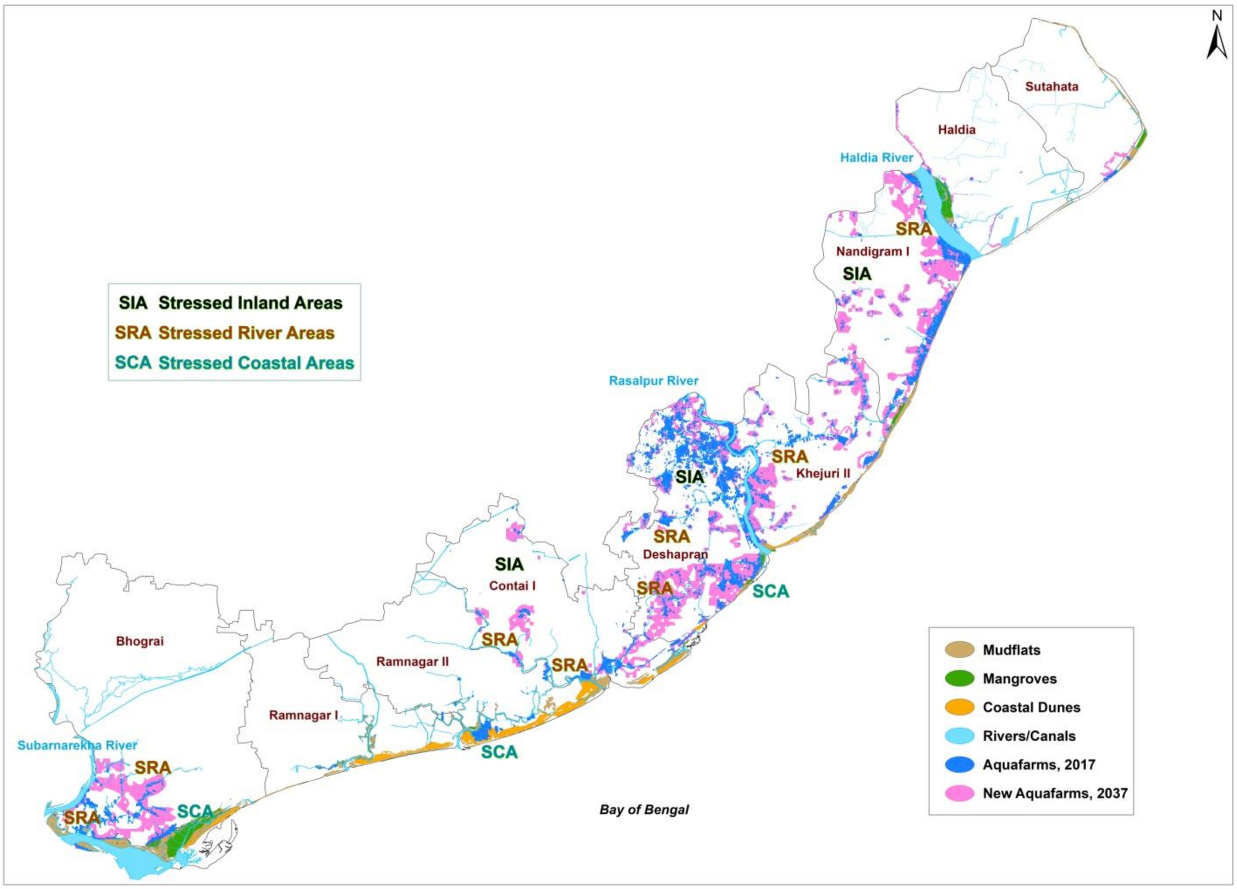

Figure 9: Stressed areas due to growth of Aquafarms in the western bank of Hooghly Estuary

Table 2: Impact of Aquafarms (*as per the study*)

Impact of rapid growth of Aquafarms		
Inland	**Near rivers**	**Along the Coast**
Loss of Cultivation lands. Decreased traditional agricultural activities. Lack of farm workers.	Increased encroachments of aquafarms along the banks. New feeder canals for aquafarms. Lack of water for other purposes. Depletion of water quality. Soil quality degradation.	Loss of natural coastal features such as mangroves and mudflats. Rapid conversion of coastal zones for human occupation.
Stress Rate : As of 2017 12% As of 2037 18%	26% 38%	9% 13%

5. Conclusion

Haphazard growth of aquaculture may provide livelihood opportunities for the locals. But this tremendous increase would vulnerable the agriculture by transforming the cultivable lands into aqua farms as well as threaten the coastal features like mangroves and mudflats. Temporal analysis indicates that 7% of agricultural area been depleted in 2017due to intensification of aquafarms and this alarming growth caused 9% stress rate on the coast. Mushrooming growth of aquafarms degraded 8% of mangrove extent in this region. It is harbingered from the prediction model that transition rate of crop land to aquafarms would accelerate to 20 % by 2037 that pose menace to both inland and coastal features. Certain regulations should be imposed on the development activities so that it would be in sustained way without harming the other landscape. Regular trajection of spatial extent of land use/land cover features and prediction of their coverage will guide to frame policy in order to conserve the coast as well as the inland features.

Acknowledgement

We thank the Director and division chair, National Centre for Sustainable Coastal Management (NCSCM), for their encouragement and support for this study. The authors express their gratitude to Ministry of Environment Forests and Climate Change, New Delhi and the World Bank, New Delhi for their continuous support in capacity development activities of NCSCM. The opinions expressed in this publication are those of the authors concerned and do not necessarily represent the views of the organization that they are attached.

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Authors' Biography

Rajakumari S- is a senior geospatial scientist working in the National Centre for Sustainable Coastal Management (NCSCM), an institute under the Ministry of Environment, Forest and Climate Change in Chennai, since 2012. She has 18 years of experience in various applications of Remote Sensing and GIS for coastal areas. Priorly she was working as project scientist in Integrated Coastal and Marine area Management (ICMAM) in Chennai, India. Dr Rajakumari was involved in some of the national level projects like COMAPS, Delineation of India's coastal sediment cells, Mapping of Ecologically Sensitive areas (mangroves and mudflats) of India. She has presented various papers in preferred journals and also contributed a book chapter. She has conducted many training workshops for young researchers and government personnel on the applications of Remote Sensing and GIS to coastal regions. Dr Rajakumari also involves herself in the field surveys undertaken for the studies. She has also extended her research activities in the form of guideship to post graduate students in applications of advance tools and techniques of Remote Sensing and GIS for their academics.

Sundari S- is a Remote Sensing and GIS expert presently working in the project mode in the National Centre for Sustainable Coastal Management (NCSCM), an institute under the Ministry of Environment, Forest and Climate Change (MoEF&CC) placed in Chennai, India. She has about 8 years of robust experience in the field. Her technical supports were appreciated in some of the national level projects such as Mapping of shoreline status of West and East coast of India in 1:50000 scale, Mapping of Ecologically Sensitive areas (mangroves and mudflats) of India and Delineation of Sediment cells for the Indian Coast. She extends her effective guidance to post graduate students for their academic projects on geospatial aspects. Sundari is also keen in participating in the Remote Sensing and GIS field surveys.

