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Climate change and coastal aquaculture in West Godavari District, Andhra Pradesh: Impacts, vulnerability, adaptations and mitigations for resilience

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ABSTRACT

The predictions of climate change during the recent decades viz., consistent warming trends (increase in frequency of hot days and multiple-day heat wave), increase in extreme rains, and more frequent and intense extreme weather events (flood, cyclone and drought) has greater impact on aquaculture. This impact has been disproportionately felt by small-scale farmers who are already amongst the poor and vulnerable members of the society. The present study in West Godavari District of Andhra Pradesh documented the climate change events experienced by aqua farmers in brackishwater and freshwater areas and their perceptions, attitudes, risk management behaviour, adaptive capacities and impacts on aquatic farming systems through focus group discussion (FGD), extensive survey of 120 farmers through standard questionnaires, and stakeholder workshop (SW). Assessment based on consequence and livelihood scores revealed that seasonal variations with 20-40% loss in production was the highest risk in both the areas followed by cyclone in brackishwater and high temperature in freshwater areas. Though not very common in every year, cyclones, the major extreme climatic event results in 50 to 100% loss in production. Among the studied aqua farmers, 14% were highly vulnerable to climate change, whereas 55% were moderately vulnerable. Farmer's adaptation measures, science and technology solutions and policy adaptation measures are discussed to make aquaculture as climate resilient.

Key words: Coastal aquaculture, climate change, vulnerability, adaptation, Andhra Pradesh

The impact of climate change (CC) is likely to have serious influence on agriculture, fisheries, and aquaculture sectors and eventually on the food security and livelihoods of a large section of the rural population in developing countries (IPCC, 2007). The Stern Review on Economics of CC concluded that 'climate change threatens the basic elements of life for people around the world, access to water, food production, health, and use of land and the environment' (Stern, 2007). In this context, the availability and access to fish supplies will become an increasingly critical issue as a source of quality protein, particularly to rural populations in the developing world, of which food fish accounts for over 40 per cent of the animal protein intake.

Aquaculture is known to be impacted by many facets of climate change, such as temperature, precipitation, drought, storms/floods, sea level rise (De Silva and Soto, 2009; Ponniah and Muralidhar, 2009). There is a trend of increasing surface temperature and decreasing rainfall on the Indian subcontinent (Singh and Sontakke, 2002). Annual mean temperature over the Indian subcontinent could increase in the range between 3.5 and 5.5° C by 2080 (Lal *et al*., 2001). All these studies show that India could experience warmer and wetter conditions as a result of climate change including an increase in the frequency and intensity of heavy rains and extreme climatic events. Impacts of CC on the fisheries sector in India (Sugunan and Maurye, 2003), as well as globally (Cochrane et al., 2009; De Silva and Soto, 2009), in spite of its economic value as well as a means of livelihoods, have not got the attention that it deserves. Hence, a study was carried to increase our understanding on CC events, impacts and risks perceived by shrimp farmers and their vulnerability, and formulate appropriate strategies to increase the adaptive capacity of the farmers.

MATERIALS AND METHODS

Study area

Andhra Pradesh (AP) contributes more than half of the country's shrimp production and has been in the forefront since the beginning of shrimp farming in the early 1980s. West Godavari District in AP (Area -7742 km^2; latitude and longitude -17°N and 81.17°E) was identified to carry out the present study in 2011 due to (i) designated by Planning Commission of the country as one of the hundred districts vulnerable to climate change (ii) shrimp farming is being practiced in larger area including both summer and winter crops in brackish and freshwater areas compared to other districts in the state.

Methodology to study impact of CC on aquaculture

In order to assess the CC events, perceived impacts, risk assessment, vulnerability, adaptations and mitigations a three stage robust methodology was followed as suggested by Muralidhar et al. (2010).

i. Focus group discussions (FGDs) were held with only 30 farmers at a rural informal setting in two villages of the district viz., Darbharevu representing shrimp farming in brackishwater area and Akivedu for freshwater area to document farmers felt exposure to climatic variations, extreme climatic events, and their impacts including economic impact (production/ economic loss), risk assessment, and mapping of seasonal and cropping calendars. The farmers were divided into five groups depending on their geographical location. Each group after discussion, gave a consensus opinion in a specified colour card on every aspect. To calculate the risk assessment, score of likelihood and consequence for each CC event was collected from each respondent in the group. For each event, group wise mean likelihood and consequence scores were worked out. The grand mean of the groups on likelihood and consequence was used for risk assessment. Based on the risk assessment score, the CC events were ranked and prioritized.

ii. In-depth farm survey was done with 120 practicing shrimp farmers, identified based on stratified random sampling in coastal *mandals* (sub-district administrative unit) of the district and collected data on CC impacts, exposure, sensitivity, farming practices, infrastructure, institutions, socio-economics, adaptations and mitigation measures.

iii. Stakeholder workshop at the district level involving representatives of all key stakeholders to identify farmer, researcher and policy adaptations for the CC impacts identified in the FGDs, priortise with a time line and fix the responsibility of an agency.

Vulnerability of shrimp farming to CC

Vulnerability of shrimp farming to climate change was operationalised as the susceptibility of shrimp farming to climate disturbances and determined by its exposure to perturbations, sensitivity to perturbations, and the capacity to adapt. Therefore, for the present study vulnerability is the function of exposure, sensitivity and adaptive capacity of 120 farmers i.e., Vulnerability = *f* (exposure, sensitivity & adaptive capacity).

Exposure was operationalised as experiencing a particular climate change event or phenomena by the farmer and the frequency of its occurrence. The exposure score for each climate change event was calculated by multiplying the exposure score with likelihood score and added to arrive an individual's exposure score. Sensitivity was operationalised as the consequences (positive and negative) of a climate change event or phenomena on aqua farming in terms of economic gain/loss. Positive and negative consequences were measured on a five point rating scale as 5 for disastrous (complete loss of livelihood i.e., loss of stock and infrastructure), 4 for extremely negative (more than 50% loss in production), 3 for moderately negative (25 to 50% loss in production), 2 for minor negative (10-25% loss in production), and 1 for little negative (less than 10% loss in production).

Adaptations refer to planned (with the help of the government) and autonomous (individuals themselves). Planned adaption was operationalised as the extent of provision of adaptive measures by the government and public institutions during the CC events and their perceived usefulness in minimizing the negative consequences. Autonomous adaptations were operationalised as the measures adopted by the individual farmer in response to the CC event and their perceived worth in minimizing the negative consequences. Each adaptation measure score was calculated by multiplying its score with salvage value. Finally the planned and autonomous adaptation scores were added to get an individual's adaptation score. Adaptive capacity was operationalised as extent of abilities and resources exist with the farmer to cope with CC impacts and based on extensive literature survey and relevancy, about 21 indicators were identified in assessment of adaptive capacity. Adaptive capacity score of an individual farmer was obtained by adding the scores of all the 21 identified indicators.

Vulnerability calculation

The exposure, sensitivity and adaptive capacity scores were normalized to render it as a dimensionless measure using the formula.

S_i *normalized* = $5\ (S_i - S_i\ min\ /\ S_i\ max - S_i\ min)$, *where* S_i *is the* i^{th} *indicator value.*

The vulnerability was calculated using the formula suggested by World Bank (2010). Vulnerability levels were categorized on a scale of 0-5 as very low (0 – 1.0), low (1.1 -2.0), moderate (2.1-3.0), high (3.1- 4.0) and very high (4.1-5.0).

Vulnerability = 1/3 (Exposure + Sensitivity + (1-Adaptive capacity)

Statistical analysis

Descriptive statistics were employed for general observations on climate change. The risk rating (RR) was calculated for each farmer and RR, economic risk and economic loss per event, and production loss per event between each CC type were compared through one-way ANOVA and Duncan multiple range tests. All the statistical analysis was done using SPSS.

RESULTS AND DISCUSSION

Shrimp farming systems and practices

The tiger prawn, *Penaeus monodon* was the main species cultured in the study area. The culture systems adopted in the district vary greatly depending on the inputs available as well as on the investment capabilities of the farmers. There is a high prevalence of usage of water from irrigation canals and drains. Most farmers in this region use a reduced water exchange system (20-30% water exchange per month). Recently farmers are practicing zero-water-exchange systems. This shift improves water quality through fast digestion of organic waste and without production of toxic metabolites.

Seasonal and crop calendar

The major climate regime of the district is based on the monsoons. The summer season lasts from March to June/July with peak season from May to June. Approximately 70% of the total annual rainfall is confined to the southwest monsoon season from June to September with peak rainy season in July and August, though September to December months also receives rainfall. Winter was from November to February with peak winter in December and January. Crop planning meetings were conducted in January for the summer crop, which is important for this region, and pond preparation activity was carried out during January and February, followed by stocking in February and March. Culture period is from February/March to July with the harvesting in the month of June and July.

Perception of CC events and risk assessment

The perception of farmers through FGDs indicated that in both the areas practicing shrimp farming in brackishwater and freshwater, seasonal variations (SV) followed by high temperature (HT), cyclone (CYC) and uneven (irregular) rainfall (IRF) in freshwater farming area and CYC and IRF in brackishwater farming area (Table 1) were the major CC events. The results of questionnaire survey showed that SV (108) was the major CC event perceived followed by CYC (98), HT (91) and IRF (84) (Table 2). The CC events identified by both FGDs and farmer's survey were more or less similar. There was a significant difference in the risk rating mean values for all the CC events. A significant difference was observed only between SV and other CC events and impacts with respect to their likelihood occurrence and not among the remaining CC events. There was a significant difference in the consequence rating between the CYC and other events. The risk matrix indicated that SV was under high risk category followed by CYC, HT and IRF.

CC impacts, adaptation measures and adaptation capacity

The impacts of climate change on shrimp farming could occur directly or indirectly and in some instances the impacts cannot be attributed to one single factor/ facet of climate change. The impact of the identified CC events on aquaculture and the adaptation measures are presented in Table 3. Shrimp farming has to adapt to seasonal changes by following better

Table 1 : Risk assessment of climate change events in brackish and freshwater shrimp farming areas (Focus group discussion)

Shrimp farming area	Likelihood score (Av. Values)	Consequence score (Av. Values)	Risk rating	Ranking
Freshwater shrimp farming area				
Seasonal Variation	4.7	2.7	12.69	1
High Temperature	4	2.8	11.2	2
Irregular rainfall	3.5	3	10.5	4
Cyclone	4	2.7	10.8	3
Brackishwater shrimp farming area				
Seasonal Variation	4.85	3.31	16.03	1
Irregular rainfall	4.31	3.39	14.58	3
Cyclone	4.54	3.46	15.71	2

Table 2 : Climate change and impacts perceived by shrimp farmers (n=120 through questionnaire survey)

Climate change event	Observation (Yes/No)	Likelihood rating (1-5)	Consequence rating (-5 to +5)	Risk rating	Ranking
Seasonal variation	108 /12	3 to 5 (4.24^{a} ±0.56)	-4 to -3 (-3.39^{b} ± 0.83)	-20 to -9 (-14.37^{a} ± 4)	1
High temperature	91/29	3 to 5 (4.06^{b} ±0.42)	-3 to -2 (-2.86^{c} ± 1.5)	-15 to -6 (-11.61^{c}± 7.2)	3
Cyclone	98/22	3 to 4 (3.12^{b}± 0.38)	-5 to -3 (-4.24^{a} ± 0.54)	-20 to -9 (-13.23^{b} ± 4.5)	2
Irregular rainfall	84/36	3 to 4 (3.35^{b} ± 0.29)	-4 to -3 (-3.12^{b} ± 0.74)	-16 to -9 (-10.45^{d} ± 5.5)	4

Note : The average values with different superscript alphabets with in the same column are significantly different ($p<0.05$)

Table 3 : Climate change events and their impacts, farmer's adaptation measures and economic loss in shrimp aquaculture

Events and impacts	Adaptation	Economic loss
1. Seasonal variation		
Disease Problem (WSSV, Loose shell, Vibrio)	Pre-mature harvesting	20% increase in cost of production and 20-40% economic loss. (loss depends on biomass size) Rs.60,000 loss if DOC is less than 60 days
Sudden variations in temperature	Change in stocking time and water exchange	
DO problem	More aeration	
Failure of crop due to high temperature	Water top-up Increase water depth	
Water quality problems - Reduced pH, Water colour change, bloom crash, increase in microsyst, blue green algae and increase in salinity	Probiotic application Zero water exchange	
2. Change in rainfall pattern		
Heavy rainfall Decrease in temperature and water salinity, low feed intake, decrease in growth causes increase in disease	Application of chemicals	50% loss due to disease 20% increase in production cost
Low rainfall Disease problem Changes in water quality (bloom crash, low pH), increase in bacterial load, reduced DO	Lime application for bloom crash (150 Kg/ha) Calcium hydroxide application to lower pH	Increase in the usage of chemicals 20% increase in production cost
3. Cyclones		
Loss of pond environment, Breaking of bunds water deterioration, disease outbreak, infrastructure damage	Shifting of infrastructure and materials in the farm, post stocking, adjustable harvesting, netting around the farm	100% loss

management practices (BMPs) at farm level. The salinity increase and decrease are the major impacts that are very much relevant to the shrimp farming as a result of climate change events. At a higher scale, extreme climatic events like cyclone resulted in 100% loss, where as seasonal variations with respect to temperature and rainfall resulted in 20 to 50% loss in production. Farmers are following different types of adaptive measures for each CC event.

Water exchange, feeding practice, lime application, adjustable harvesting and post stocking were the adaptive measures reported by farmers to cope up with the losses due to SV. Changes in average precipitation, potential increase in seasonal and annual variability and extremes are likely to be the most significant drivers of climate change in shrimp aquaculture. Reduced annual rainfall, dry season rainfall, and the resulting growing season length are likely to impact the shrimp farming and could lead to conflict with other agricultural, industrial and domestic users in water scarce areas. Timely onset and sudden withdrawal of monsoon causes increase in salinity during later stages of the culture period especially in low tidal amplitude areas and could lead to conflict with other users for freshwater usage. Break in monsoon i.e., dry spell conditions for two to three weeks consecutively and early withdrawal of monsoon can lead to salinity build up in creeks and reduces water availability. The problem of water scarcity and higher salinity are very site-specific with wide variations, depending on the tidal amplitude, water current and inflow of freshwater. The tidal amplitude is relatively low in the study area and when there is a failure of monsoon, these bar-mouths may not open and lead to a scarcity of water in the source water bodies. Further, the lack of rains during summer months will lead to an increase in the salinity of water bodies beyond the tolerable limits of the cultured shrimps (Preston *et al.,* 2001). Changes in suspended sediment and nutrient loads resulting from altered rainfall patterns will also affect aquaculture in brackishwater ponds (Nell, 1993).

As aquaculture ponds are typically shallow and turbid, solar radiation is likely to have an important influence on water temperature (Kutty, 1987). A change in temperature of only a few degrees might mean the difference between a successful aquaculture venture and an unsuccessful one (Pittock, 2003). The variations in pond temperature had pronounced impacts on growth (Lehtonen, 1996) and on farm prawn production with maximal growth rates of tiger prawns (*Penaeus monodon*) during sustained periods of warmer pond water (Jackson & Wang 1998). Increased temperatures will affect pond evaporation rates and results in increased pond salinity, which could adversely affect less salt-tolerant species. The negative impacts of high temperatures on aquaculture are alterations in water quality in water bodies, worsening dry season mortality, bringing new predators and pathogens, and changing the abundance of food available to fishery species, and shifts in dissolved oxygen levels. These have been reported to increase in the intensity and frequency of disease outbreaks (Harvell *et al.,* 2002; Vilchis *et al.,* 2005) and in more frequent algal blooms in coastal areas (Kent and Poppe, 1998). Changes in temperature would change plankton community structure. Dinoflagellates have advanced their seasonal peak in response to warming, while diatoms have shown no consistent pattern of change (Edwards and Richardson, 2004).

Shifting of infrastructure and materials in the farm, post stocking, adjustable harvesting, netting around the farm and the assistance from the Government are found to be some significant adaptive measures followed in the event of cyclones. Many of the farmers were not willing to change the crop or shift the occupation. Govt. help and material shifting were correlated more with the level of success. Increase in the intensity and/or frequency of extreme climatic events such as Nisha cyclone in November 2008 (Tamil Nadu), Aila cyclone in May 2009 (West Bengal) and Krishna River floods in October 2009 (AP) caused damage to infrastructure and shrimp stock (Ponniah and Muralidhar, 2009; Muralidhar et al., 2009) and the associated negative impacts such as changes in salinity, heavy siltation and introduction of disease or predators into aquaculture facilities along with the flooded water would result in crop losses.

The mitigation measures for stakeholders to increase the adaptation capacity of farmers include online monitoring of weather conditions and providing timely information to farmers on weather reports, region wise database to identify the seasonal variations on pond water parameters, educating the farmers to adopt BMPs, information on the occurrence of diseases in the changing climate scenario and remedial measures, pond dynamic studies including plankton diversity, studies on physiological changes in fish/shrimp species diversification studies and identifying species which can tolerate abiotic stress such as salinity and temperature variations in relation to CC and extreme climatic events, treating aquaculture on par with agriculture, provision of subsidy and uninterrupted power supply, dredging of canals to provide quality water in sufficient quantity and change in insurance policy for providing compensation to the farmers in the case of loss of stock due to extreme climatic events. These recommendations will increase the adaptation capacity of farmers to cope with CC events and to achieve climate resilient aquaculture.

Vulnerability of shrimp farmers to CC

Vulnerability is also described as the extent to which a system is susceptible to sustaining damage from climate change (Schneider *et al*., 2001). The vulnerability index in the study area revealed that about 55, 18, 14 and 13% of farmers were moderate, very low, high and low vulnerable to climatic variations and extreme events. The AP coast especially in the low lying zones along the Krishna and Godavari deltas are highly vulnerable to sea level rise (Nageswara Rao et al., 2007; 2008). About 43% (442.4 km) of the 1,030-km-long AP coast (Krishna, Godavari and Pennar delta front coastal sectors) is under very high-risk category. If the sea level rises by 0.59 m as predicted by Nicholls and Lowe (2004) and IPCC (2007), an area of about 565 km^2 would be submerged under the new low-tide level along the entire AP coast of which 150 km^2 would be in the Krishna–Godavari delta region alone.

CONCLUSIONS

Seasonal variations, high temperature, irregular rainfall and cyclone were the major climate change events for coastal aquaculture in brackish and freshwater farming areas. Alterations in water quality like increase and decrease in salinity and temperature, and changes in dissolved oxygen are the major impacts that are very much relevant to the shrimp farming as a result of climate change. Seasonal variations including temperature and rainfall resulted in 20 to 50% loss and cyclones up to 100% loss in shrimp production. Shrimp farming has to adapt to seasonal changes by following better management practices at farm level. A very strong focus on building general adaptive capacity can help the aquaculture farmers to become climate resilient.

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