Case study on the impacts of climate change on shrimp farming and developing adaptation measures for small-scale shrimp farmers in Krishna District, Andhra Pradesh, India

Case study report

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The report communicates the Aqua Climate project Indian case study Focus Group Discussion and Stakeholder Workshop results on perception of climate change impacts and adaptation of shrimp farming.

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About AQUACLIMATE

AQUACLIMATE is a three year project funded by the Ministry of Foreign Affairs, Norway, through the Royal Norwegian Embassy, Bangkok, Thailand.

Title of project: Strengthening Adaptive Capacities to the Impacts of Climate Change in Resource-poor Small-scale Aquaculture and Aquatic Resources-dependent Sector in the South and South-east Asian Region

Disclaimer

List of acronyms

ANGARU	Acharya NG Ranga Agricultural University
AP	Andhra Pradesh
BMPs	Better Management Practices
BSCC	Broodstock Collection Centre
BSPs	Bio-security protocols
CAA	Coastal Aquaculture Authority
CIBA	Central Institute of Brackishwater Aquaculture
CIFA	Central Institute of Freshwater Aquaculture
CIFE	Central Institute of Fisheries Education
CMFRI	Central Marine Fisheries Research Institute
COC	Code of Conduct
CoF	College of Fisheries
CoP	Code of Practice
CWC	Central Water Commission
DoA	Department of Agriculture
DoF	Department of Fisheries
EB	Electricity Board
FAO	Food and Agriculture Organization of the United Nations
FCR	Feed Conversion Ratio
FGD	Focus Group Discussion
IITM	Indian Institute of Tropical Meteorology
IMD	Indian Meteorological Department
IPCC	Inter-Governmental Panel on Climate Change
KVK	Krishi Vignan Kendra
MoEF	Ministry of Environment and Forestry
MPEDA	The Marine Products Export Development Authority
NACA	Network of Aquaculture Centers in Asia-Pacific
NaCSA	National Centre for Sustainable Aquaculture
NFDB	National Fisheries Development Board
NIH	National Institute of Hydrology
PCR	Polymerase Chain Reaction
PL	Postlarva, Postlarvae (plural form)
RI	Research Institute
SIFT	State Institute of Fisheries technology
SW	Stakeholder Workshop

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Executive summary

Tiger shrimp, *Penaeus monodon* has been the mainstay of India's seafood exports for the past two and half decades (recently, *Litopenaeus vannamei* is introduced) and has immense potential as a foreign exchange earner. It also has substantial contribution towards socio-economic development in terms of income and employment. Shrimp aquaculture is threatened by changes in temperature, precipitation, drought and extreme climatic events (cyclones, storms, floods) that affect infrastructure and livelihoods which can impact aquaculture both negatively and positively. Ecological changes, inundation of low-lying lands and saline intrusions into freshwater regions are likely to cause substantial dislocation of communities and disruption of farming systems. In the face of potential complexities of climate change interactions and their possible scale of impact, the primary challenge for the shrimp aquaculture sector will be to deliver food supply, strengthen economic output and maintain and enhance food security. It is expected that the climate change impacts will be disproportionately felt by small-scale shrimp farmers who are already amongst the most poor and vulnerable members of society. The small scale farmers are typically unorganized and most of the farmers did not have access to technological innovations and scientific applications. There is a need to forecast the likely effects of climate change on the shrimp aquaculture sector and to develop strategies to assist farmers and rural communities to adapt to the upcoming changes.

The project on "Strengthening Adaptive Capacities to the Impacts of Climate Change in Resource-poor Small-scale Aquaculture and Aquatic Resources-dependent Sector in the South and South-east Asian Region" (*Aquaclimate)* funded by Norwegian Agency for Development Cooperation and coordinated by the Network of Aquaculture Centers in Asia-Pacific (NACA), Bangkok aims to strengthen the adaptive capacities of rural aqua farming communities to the impacts of climate change in four Asian countries viz., India, Sri Lanka, Vietnam and Philippines. The focus of the present study report is on mapping the small scale farmer's perceptions and attitudes towards climate change impacts and their adaptive capacities to address the impacts in Krishna District, Andhra Pradesh, India. Central Institute of Brackishwater Aquaculture (CIBA) is the national partner to conduct the study in small-scale farming clusters formed by National Centre for Sustainable Aquaculture (NaCSA).

The study area, Krishna delta coast with mudflats, mangrove swamps, and lagoons/backwaters is much more vulnerable to sea level rise in the future and is at very high-risk. It was hit by a severe flood of once in 100 years in Krishna River during October 2009 and caused heavy economic losses to shrimp farmers. The temperatures registered in summer are very high and as high as 50°C was recorded in the study area during 2007.

Farmer's perception of climate change

The use of participatory processes such as facilitated semi-structured focus group discussion at Chinnapuram and Gullalamoda, the inland and coastal shrimp farming areas of the district, facilitated stakeholder workshop, a novel technique for the shrimp farmers and stakeholders and interviewing 300 farmers through structured questionnaire helped in understanding the perceptions, vulnerability, and adaptability to climate change on small scale shrimp farmers and developing the farmers', scientific and policy adaptation measures, and the time line and organizations responsible for the implementation.

The farmers identified the important climate change events including the extreme events and ranked their importance during FGD meetings. The inland and coastal area shrimp farmers have experienced more or less similar climate change extremes though there was a difference in the order of priority. The climate change impacts identified on priority were seasonal changes, heavy rains, floods and cyclone in inland shrimp farming area and high temperature, floods, un-seasonal rain fall, low temperature, cyclone and low tidal amplitude in coastal shrimp farming areas. The seasonal changes were mainly temperature variations and delay in monsoon. The water inundation in ponds is due to heavy rainfall caused by both floods and cyclone. Cyclones are not a problem as they are not very frequently occurring event. However, if cyclone occurs with heavy rainfall, then the economic loss was hundred per cent. Floods and seasonal changes are under extreme risk category whereas heavy rain and cyclone are under high risk category in inland area. High temperature, floods and low rainfall were under high risk category while less cyclone, low tidal movement and low temperature were under medium risk category in coastal area.

Seasonal and crop calendar mapping

Month-wise shrimp farming activities were displayed on the chart and the farmers after discussions within and between the groups matched the crop activities with the seasonal changes. Crop activities such as pond preparation including repair of pond dykes, intake and sluice structures, draining and drying the ponds were taken in the dry months January and February for the first crop and May/June for the second crop. During this time the weather is dry and allows the pond bottom to dry faster. Water filling and bloom development is during February and March for the first crop and July to August/September for the second crop. The harvesting time spreads over May and June for the first crop and November/December for the second crop. Diseases were more during monsoon and post monsoon period. Hence in most of the areas second crop was not a successful one. The production, fry and market prices were also high during the first crop compared to second crop. The occurrence of floods, cyclones and high tides are of unusual occurrence in the months of May and November. Crop planning meetings were done only in societies in December and January months before the first crop and these meetings were not serious for the second crop as many of the farmers are not taking second crop.

Climate change impacts and vulnerability

Expansive survey of 300 farmers indicated that cyclones (CYC) and floods (FLD) were perceived by all the farmers and irregular seaspn (IRS), high temperature (HTEM), heavy rain (HR) and drought (DRT) were perceived by 236, 267, 272 and 177 respectively. FLD and HTEM were highest likelihood events with average scores of 4.5 and 4.6, respectively. There was a significant difference in the consequence rating between the CC events. DRT, WSI, WSD, IRS and HTEM were of less consequence to shrimp farming compared to CYC, FLD and HR. HTEM also had positive consequence as reported by some farmers in increasing the production. CYC and FLD caused more economic loss compared to other events. Highest loss of □ 102,000 was reported with FLD. Garrett scores revealed that CYC, FLD, HTEM, HR, IRS and water quality are the most weather related problems in the order at present and in the future HTEM, FLD, HR, water quality and CYC are the major problems.

Technical efficiency of farmers in overcoming the climate change impacts

Socio-economic analysis revealed that among the sampled farmers, about 41% of the farmers were educated up-to primary level, 27% up to secondary level, 8% up to university level and the remainder had no formal education. Overall, 83% (250) of the farmers had undergone at least one training course related to aquaculture and the rest had not been through any form of training. A vast majority (82%) of the farmers has shrimp farming as the main occupation. On an average 46% family members were earning members showing that family labour is an important contribution to shrimp farming. Out of those who earn, 63% (or 29% of the total sample size) were males. It is thus important to address both genders, while devising strategies or programs for improving their adaptive capacity.

A Stochastic Frontier Function was used to study the technical efficiency of the farmers. The present study attempts to explain the difference in efficiencies using socio-economic and climatic variables, a novel approach in this analysis. Technical efficiency measures the efficiency in utlization of resources. Since some farmers were using different adaptation strategies to overcome the negative effects of climate change, it was considered more pertinent to include the effect of the various strategies also along with socio-economic factors to determine whether the strategies of the farmers to climate change really help in improving their efficiencies. Among socio-economic variables, stocking density, farming experience and society membership has significant influence on the efficiencies. Among the climatic variables, cyclone storm – level of success and flood from rains – level of success, were the only two variables which were significant. Further the coefficients of these variable were positive indicating that those farmers who had successfully overcome the negative effect of cyclone storm and floods have increased their efficiency levels.

Predicted climate change scenarios for 2020 and 2050

Average maximum temperature scenarios predicted in the study area suggest that temperature would increase throughout the region. The maximum temperature will increase by 1-2 ˚C by 2020 and 2050. There will also be hot weather spells for longer periods. The present peak average temperature which occurs in May to June will be extended for two and half months in 2020 and 2050 which poses significant risks such as increase in salinity and thermal stratification resulting in dissolved oxygen problems in culture ponds. Predictions over study area indicated that the mean monthly minimum temperature will increase by 2-4°C in 2020 and 2050 comparative to the present scenario. The increase in temperature during winter months will be positive for shrimp farming leading to better food conversion rate and faster growth rate. There is not much difference in average monthly rainfall during January to May, and August, September, November and December months in 2020 and 2050 indicating that there is no serious impact on shrimp farming. Since there will not be much change in rainfall, the increase in temperatures will have adverse effect on the water availability in source waters, changes in water quality parameters thus affecting the shrimp growth performance.

Global warming potential and resource use bench marking

Energy use apparently has not been assessed for aquaculture and this may have particular relevancy in shrimp aquaculture, where it is shipped long distances for ultimate consumption. Global warming potential (GWP) and eutrophication potential (EP) values for the present shrimp culture case study were 3,920 kg CO_2e and 0.629 kg PO_4-e per ton shrimp production. It is possible that greater overall gains in energy savings can be made by improving the efficiencies of aerators and pumps in the production sector. In terms of resource use, Fish-in-Fish-out (FIFO) ratio, and estimated water use, land use and energy use per ton of shrimp production were 1.23, 12633 m^3, 5543 m^2 and 4358 MJ respectively and benchmarked against other estimates.

Adaptation measures to increase the adaptation capacity of farmers

Improving and applying knowledge on the constraints and opportunities for enhancing adaptive capacity is necessary to reduce vulnerabilities associated with climate change. The starting point for this is a common understanding of the concepts of adaptation, vulnerability, resilience, as well as an understanding of the gaps in current adaptation approaches. The most important adaptation measures are water exchange, feeding practice, lime application, adjusted harvest and delayed stocking for irregular season, high temperature and uneven rainfall distribution. Dyke height increase, shifting of machineries, netting around the farm, shifting to other occupation are the adaptive measures for cyclones/storm surges and flood, and freshwater mixing for drought. In order to increase the adaptive capacity of the farmers, requirement of financial support, insurance and relief fund have been ranked as the first priority during extreme climatic events and regarding the type of support received from the government agencies, technical assistance (from NaCSA in the present study) ranked as the top priority.

The farmer can adapt to small changes in weather patterns and short term gradual climate change but they are not prepared for rapid changes or long term continuous climate change. The farmer needs to be assisted by scientific research and technology development to find solutions that will allow them to adapt to the predicted future climate change. A very strong focus on building general adaptive capacity can help the poor shrimp aquaculture communities to cope with new challenges. The farmers should have a commitment to implement the adaptive measures at the farm level (better management practices) and all the Govt. Departments, research organizations and NGOs have to help them in increasing their adaptive capacity. Both Central and State Govt. should make strong policies on climate change with a focus to increase the adaptation capacity of all the stakeholders involved in the shrimp farming sector. Integration of climate change considerations into the policies in aquaculture sector can facilitate adaptation and ensure that they contribute to adaptive capacity from national to local levels.

Farmer technical adaptation measures

1. Strengthening and increasing the height of pond dykes and farm bunds
2. Implementation of better management practices (BMPs) related with climate change adaptation measure.
3. Use of electricity for water pumping and providing aeration during weather disturbance situations
4. Maintenance of buffer zone between the farms and water source for protection to farms against cyclones and storm surges
5. Collective planning by the farmers group to mitigate the impacts of climate change

Science and technology adaptation measures

1. Increased accuracy in predictions of weather parameters and extreme climatic events and developing guidelines for the assessment of likely damage.
2. Predictions on water availability in both fresh and brackishwater bodies and changes in salinity regimes
3. Identifying vulnerable coastlines and selection of suitable mangroves species and defence structures as bio-shields and barriers
4. Identifying species which can tolerate abiotic stress such as salinity and temperature variation as a measure of contingency planning
5. Observations on the seasonal crop pattern, animal behaviour, pond dynamics and ecosystem environment in relation to climate change and extreme climatic events.
6. Weather anomalies that trigger disease incidence and the impact of changing seasonal patterns on emergence of new diseases has to be investigated
7. Research interventions on better management practices in the context of climate change
8. Actual aeration requirements estimation and improving the efficiency of pumping and aeration
9. Development of low fish meal feed technology using plant protein sources
10. Awareness materials on climate change impacts and adaptation measures and studies on climate field school concept.

Policy recommendations

1. To recognize aquaculture on par with agriculture so that shrimp farmers can get access to institutional credit support and crop insurance at the time of extreme climatic events and electricity at low tariff.
2. To secure National Calamity Contingency Fund (NCCF) for shrimp farmers to compensate the losses due to extreme weather events.
3. To improve early warning systems on cyclones and floods.

4. To develop contingency plans to overcome losses from extreme weather events or changes in climate affecting the normal crop calendar.
5. Climate resilient structures to withstand extreme climatic events - Repair of flood bunds and improve the quality and availability of source waters through dredging and deepening of water bodies
6. To strengthen coastal systems against storm surge and sea level rise by planting tree barriers
7. To build capacity of farmers through trainings and initiation of Climate field school
8. Encouraging women's participation in future adaptation measures

Stakeholder and institutional mapping and analysis and policy frame work for implementation of adaptation measures

Key stakeholders, individuals and organizations were characterised based on their understanding on climate change issues and impacts on shrimp farming, adaptive capacity and interests in implementing them. The tasks of all the identified stakeholders related to shrimp farming and climate change such as the role they play in shrimp farming sector, financial, technical and research support, natural resources, aquaculture policy management, and, collection, maintenance and dissemination of data were analysed. The scale of CC impacts and policy frame work for the adaptation measures is shown in the framework.

SCALES	**Climate change**	**Impacts**
Ocean	Sea level rise	More brackishwater area, Salinisation of freshwater bodies
Source water	Precipitation (shift/ volume), Temperature (increase/ shift/ sudden change)	Changes in water quality (salinity, pH and nutrients)
Farm clusters		Flooding/ reduced water availability
Farm		Changes in salinity, pH, dissolved oxygen, disease incidence
	Adaptation measures	
	Who	**What**
Mandal/ Taluk	NaCSA	Training, crop planning
District	Fisheries Department	Aquaculture planning, training & licence
	PWD and Irrigation & Drainage Department	Climate resilient structures
State	Department of Fisheries	Insurance policy
National	Ministry of Agriculture and Ministry of Animal Husbandry & Fisheries	Assessment of damage due to ECEs,
	IMD and CWC	Early warning systems
	National Disaster Management Authority	National Calamity Contingency Fund
	NFDB	Funding for capacity building

1. Introduction

Global green house gases emissions will continue to grow over the next few decades even with the current climate change mitigation policies and related sustainable development practices and thus climate change (CC) is inevitable. Climate change is projected to impact broadly across ecosystems, increasing pressure on all livelihoods and food supplies, including fisheries and aquaculture sector. The demands of a growing population will require substantial increases in aquatic food supply mainly through aquaculture in the next 20 to 30 years during which climate change impacts are expected to increase. Global green house gases emissions will continue to grow over the next few decades even with the current climate change mitigation policies and related sustainable development practices. Climatic scenarios generated by computer models 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.

Brackishwater aquaculture in India is synonymous with shrimp farming and mainly carried out by small scale farmers. Shrimp aquaculture has been accepted as a vehicle for rural development, food and nutritional security for the rural masses considering its substantial contribution towards socio-economic development in terms of income and employment through the use of un-utilised and under-utilised resources in several regions of the country. Shrimp has been the mainstay of India's seafood exports as the nation ranks as one of the largest producers of the black tiger species *Penaeus monodon.* It also has immense potential as a foreign exchange earner. Shrimp contributed to 21 per cent by volume and 44 per cent by value of Indian seafood exports during 2008-09 (www.mpeda.com).

It is expected that the climate change impacts will be disproportionately felt by small-scale farmers who are already amongst the most poor and vulnerable members of society. The east coast of India is subject to frequent cyclonic storms and occasional tidal waves which cause loss of aquaculture stock and damage to aquaculture facilities. Ecological changes, inundation of low-lying lands and saline intrusion into freshwater regions are likely to cause substantial dislocation of communities and disruption of farming systems. There is a need to forecast the likely effects of climate change on the shrimp aquaculture sector and to develop strategies to assist farmers and rural communities to adapt to the upcoming changes.

1.1 Background to the project and case study

The project on “Strengthening Adaptive Capacities to the Impacts of Climate Change in Resource-poor Small-scale Aquaculture and Aquatic Resources-dependent Sector in the South and South-east Asian Region” also known as "*Aquaclimate*" aims to strengthen the adaptive capacities of rural farming communities to the impacts of climate change. The three year project focuses on small-scale aquaculture and related sectors that are comprised largely of poor people who depend on aquatic resources for their livelihoods. The project coordinated by Network of Aquaculture Centers in Asia-Pacific (NACA) is implemented in India, Vietnam, Philippines and Sri Lanka and is funded by the Norwegian Agency for Development Cooperation (NORAD).

The focus of the project is on mapping the farmer’s perceptions and attitudes towards climate change impacts and their adaptive capacities to address the impacts in specific farming sectors in the countries of Vietnam (catfish and improved extensive shrimp farming), Philippines (milkfish farming), India (improved extensive shrimp farming) and Sri Lanka (reservoir fisheries). The project is developing future scenarios of climate change impacts based on the current trends, assessing the potential adaptive measures for different aquatic farming systems and developing and prioritising better management practices, suggesting codes of practices and improved methodologies for such systems. The project is also developing guidelines for policy makers to help in framing appropriate regional adaptation strategies and associated policy developments. Interaction with stakeholders including small farmer organizations, managers, policy makers and researchers in the region to gain from their experiences, jointly develop scenarios and adaptation strategies is part of the project strategy.

1.2 Objectives and expected outputs of the Aquaclimate project

The overall project objective was to select suitable and appropriate aquatic farming systems, which provide livelihoods to small scale farmers, in each of the countries that are likely to be impacted and or subjected to different elements of climate change impacts (e.g. sea level rise, flooding, extended drought periods) and to determine/ assess the degree of vulnerability of each system, and to provide guidelines on suitable adaptive measures, ranked according to relevant criteria (e.g. economic, social, etc.) for consideration for adaptation by the communities/policy makers and so forth.

Specific Objectives

- Assess the impacts of climate change (CC) on small scale aquaculture sectors (environmental and socio-economic) in selected areas and aquatic farming systems.
- Assess the vulnerability of different aquatic farming systems to climate change.
- Explore potential adaptive measures for different aquatic farming systems.
- Prioritise better practices for the most "adaptive" aquatic farming systems.
- Develop future scenarios for small-scale shrimp aquaculture systems in India (up to 2020).
- Propose risk-mitigating strategies compatible with the scenarios.
- Determine awareness/knowledge level, perceptions of risks, and attitudes of farmers towards perceived risks from climate change.
- Determine risk-management behaviours and strategies of farmers to climate change induced risks.
- Develop guidelines for policy measures and decision support tools.
- Benchmark adaptive capacities of small farming households.
- Develop wider awareness of the results by publishing and disseminating through various sources and networks.

1.2.1 Expected outputs

The project will provide small-scale farmers with strategies to maintain their resilience in the face of climatic change. Outputs of the project are recommendations that address the environmental and social changes (and conflicts) likely to arise from climate change impacts on the respective farming systems, improve management/governance mechanisms and decision support systems, build capacity and strengthen institutional partnerships and alliances. It will provide information for investments in research, technology development and transfer, public education, training, infrastructure and systems, markets, financial and other support services for the poor farmers and aquatic resource users. End users of the outputs from the project are farmers, policy makers, academia, producer organizations, regional organizations and Non Governmental Organizations (NGOs).

1.3 Project implementation

The project is implemented by international and national partners, with each partner bringing different areas of expertise and having different areas of responsibility within the project.

The international project partners for the study are:

- Network of Aquaculture Centers in Asia-Pacific (NACA), Bangkok, Thailand
- Faculty of Fisheries, Kasetsart University, Bangkok, Thailand
- Bioforsk – The Norwegian Institute for Agricultural and Environmental Research- Norway
- Akvaplan-niva AS – Tromso, Norway

The project will be implemented via five work packages, as follows:

- Assessment of impacts of climate change on small-scale aquatic farming systems risk perceptions, attitudes and risk management behaviour status of resiliency, adaptive capacities and adaptation strategies of small-scale farmers.
- Developing adaptive solutions and scenario-building of the changes on the resources and livelihoods options of poor and small aquaculture households, and the risks and opportunities presented by climate change.
- Policy and analysis and adaptation strategy development.
- Project coordination, results dissemination and follow up action.

1.4 Indian case study

The Aquaclimate project case study in India will investigate the climate change impacts and adaptation of extensive shrimp farming. The information on the likely impacts of climate change on shrimp farming is very limited and hence it is essential that there is concerted research effort to understand the impacts and develop adaptive measures. Shrimp aquaculture is threatened by changes in temperature, precipitation, drought, storms/floods that affect infrastructure and livelihoods which can impact aquaculture both negatively and positively. However, proper focus was not given to this sector compared to agriculture in terms of the damage assessment, relief measures, and crop insurance schemes.

This case study aims to assess the degree of vulnerability of the small-scale shrimp farmers in Andhra Pradesh, and to provide guidelines on suitable adaptive measures to assist them to adapt to climate change and sustain their livelihoods. Central Institute of Brackishwater Aquaculture (CIBA) is the national partner to conduct a comprehensive study, in conjunction with the National Centre for Sustainable Aquaculture (NaCSA), part of the MPEDA. NaCSA societies in Krishna District of AP have been selected to study the impacts and adaptation of small scale shrimp farmers in this Aquaclimate project.

The expected deliverables from this sub- project are likely to be:

- A knowledge on different scenarios on impacts of climate change impacts, for shrimp farming systems
- The impacts of extreme events on shrimp farming systems.
- Range of adaptation measures to different climatic change elements and suggested improvements to practices and or introduction of new practices to maintain livelihoods of aquatic farming systems.
- A series of publications and reports and associated dissemination materials targeted at different audiences.

1.5 Shrimp farming in Andhra Pradesh

It is estimated that the country has 1.2 million hectares (ha) of brackishwater area and 5.4 million ha of freshwater sites for development of shrimp and fish farming respectively. Andhra

Pradesh (AP) contributes more than half of country's shrimp production in India and the state has been in the forefront since the beginning. Though the ideal tidal amplitude conditions of 1-2 m daily range with an absolute annual range of 2-3 m for shrimp farming do not exist in the state, shrimp aquaculture expanded through the excavation of ponds to depths that would allow tidal water exchange or to avoid excavation by putting a dyke around and use pumps for filling and water exchange. Both the processes introduce heavy cost elements and technical uncertainties, risking both the technical and economic viability. The water quality in respect of year-round salinity distribution, chemical and physical nature of soil, and availability of seed in the state are favorable for coastal shrimp aquaculture. Availability of vast tracts of saline lands coupled with abundant quantity of wild seeds and strong export demand for shrimp were initially responsible for attracting the entrepreneurs towards shrimp farming.

The Tiger prawn, *Penaeus monodon* was the main species cultured. The development of more commercial hatcheries coupled with credit facilities from commercial banks and technical and financial assistance programs from The Marine Products Export Development Authority (MPEDA) led to a phenomenal increase in the area under shrimp farming. A large number of corporate shrimp farms with foreign collaboration also emerged adopting scientific culture system with integrated facilities for production of shrimp seeds, feed, and processing, but did not continue this trend for long as they failed to make profits, and consequently, shrimp farming became more or less a small farmer activity. The small scale farmers were unorganized and most of the farmers did not have access to technological innovations and scientific applications.

Small scale farmers are innovative and productive, but because of poor organization, lack of skills, inadequate information, and knowledge base, they are vulnerable to the numerous risks and hazards that impact their livelihoods and farm productivity. Shrimp farms are operated on both leased out government/private lands and owner operated lands. A credit system functioned throughout the sector, operated and controlled primarily and intermediaries also acted as input suppliers and providers of credit at each stage in the supply chain by buying back the harvested shrimp. On average, farmers end up paying a whopping 30% interest on the loans from the intermediaries that affect the profitability of their operations.

1.5.1 Shrimp production details and farming systems

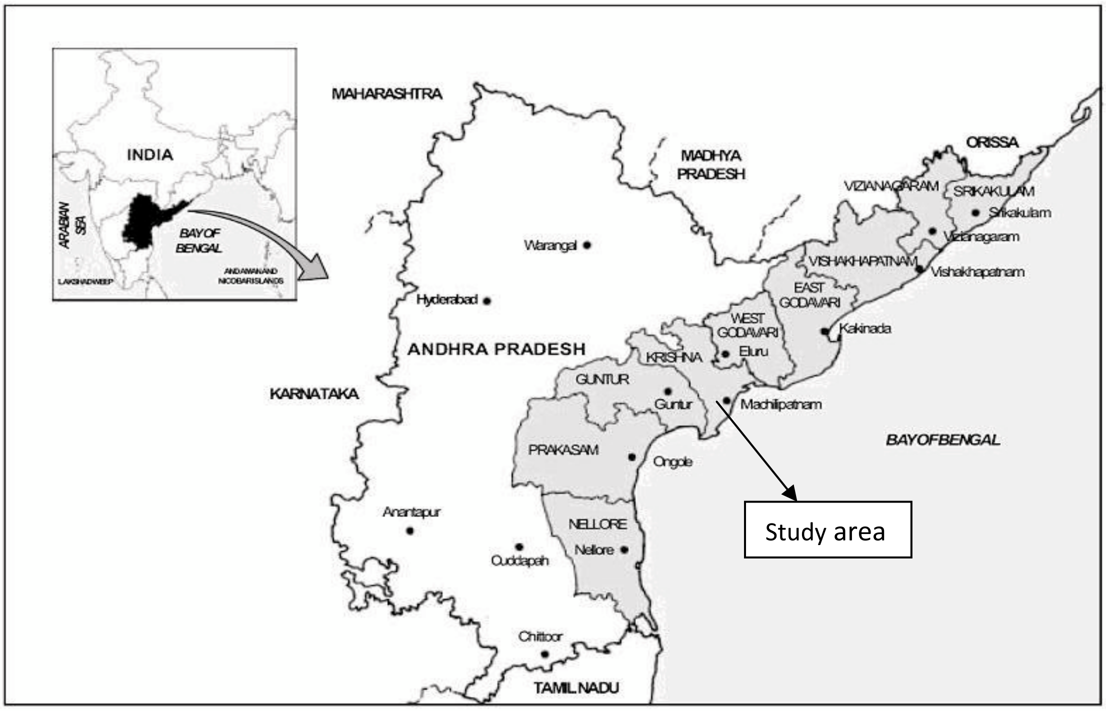
The culture systems adopted in the state vary greatly depending on the inputs available in any particular region as well as on the investment capabilities of the farmer. An average production of 500 to 1500 kg is expected per crop by adopting scientific farming practice in low input systems. Semi-intensive farming technology with production levels reaching 4 to 6 tonnes/ha has been demonstrated (Surendran *et al*., 1991). The culture practice was also gradually intensified and varied levels of intensification were noticed depending on the investment capabilities of the farmer/ entrepreneur.

In 1993, viral diseases such as Monodon baculo virus and white spot virus disease affected the farmed shrimp due to unplanned and uncontrolled development of shrimp farms, heavy stocking densities and poor farm management practices and there was a slump in shrimp farming. Later in 1996 following the verdict of Supreme Court and the establishment of Aquaculture Authority with powers to issue licenses and guidelines, the shrimp culture sector is gradually going through a regulated regime and is slowly returning to its previous production level.

1.5.2 Shrimp aquaculture statistics

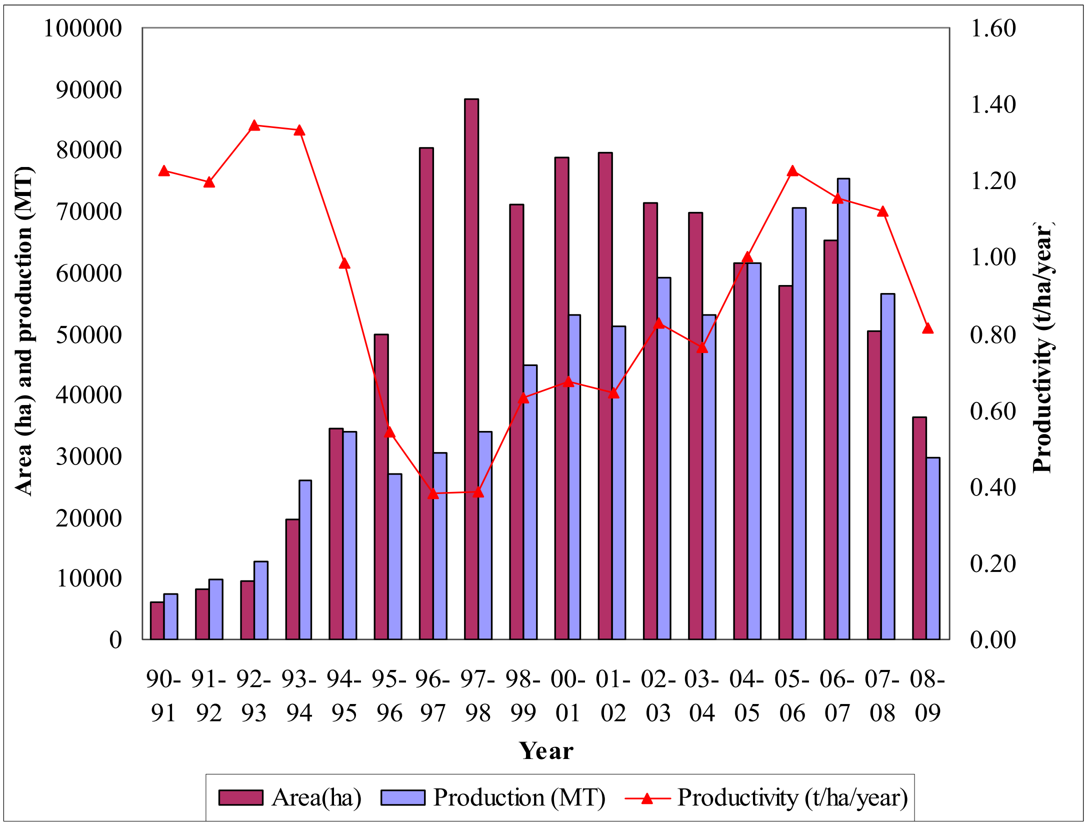
Andhra Pradesh (AP) is the fourth largest state in India in terms of geographical area (275,068 sq. km) and fifth largest in terms of population (75.7 million in 2001). The state has a coastline of 1050 km with two gigantic delta systems formed by the rivers Godavari and Krishna that encompass major wetlands of the state. The length of rivers and canals in the state was 11,514 km and the area under reservoirs and tanks, and ponds was 0.234 and 0.517 million ha respectively (GOI, 2006). The potential area available for brackishwater aquaculture in the state was 0.15 million ha with a network of 172 brackish water bodies in 9 coastal districts (Aquaculture Authority, 2001) (Fig.1). This accounts for 12.6 % of the total potential area in the country (1.2 million ha). Out of total potential area 84,951 ha (56.63%) has been developed for shrimp farming (MPEDA, 2006).

Shrimp's belonging to *Penaeus monodon* is cultured extensively in the state. Growth of shrimp farming in AP was phenomenal during the years 1990-1994. In 1990, a total of 6,000 ha was under shrimp farming which has risen to about 88,290 ha during 1997 (Fig.2) and then a decreasing trend was observed continuously registering an area of 36,395 ha during 2008-09 (MPEDA statistics). The productivity of shrimp was more than one ton/ha/year during 1990-91 (1.23 ton/ha/year) to 1993-94 (1.33 ton/ha/year) and then decreased to less than one in subsequent years due to disease problems (lowest productivity of 0.38 ton/ha/year during 1996-97) and again increased to more than one from 2004-05. Most of the area is based on brackishwater/ estuarine creeks (96%) and the remaining area (4.0 %) is based on sea. Department of Fisheries, Govt. of AP conducted a rapid macro survey on the shrimp farmingarea details during 2004-05. It is estimated that out of total area developed into shrimp ponds (84,163 ha) in the state, 70.1 % area was within coastal regulation zone (CRZ) and 29.9 % of the area was located beyond CRZ and out of the total area under culture (53,247 ha) during the same period, 61.8 % area was within CRZ and 38.2 % of the area was outside CRZ.



Source: Coastal Aquaculture Authority (2001)

Fig.1. Map of Andhra Pradesh showing coastal shrimp growing districts (Arrow shows the location of study area: - Latitude: 15º 43' N and 17º 10' N and Longitude: 80º 0' and 81º 33' of E)



* Data for 1999-2000 and 2000-2001 is not available. (Source: MPEDA statistics)

Fig. 2. Area, production and productivity details of shrimp farming in Andhra Pradesh

1.5.3 Distribution of shrimp farms based on size of farms

The farming of shrimp is largely dependent on small holdings of less than 2 ha and these farms account for 90% of the total area utilized for shrimp culture, 7% of farms are between 2 and 5 ha and the remainder has an area of greater than 5 ha (Yadava, 2002; MPEDA, 2006). As per the recent survey of 2004-05, 94 % of the total developed area for shrimp farming in the state was less than 2.0 ha farm holding (53,908 ha); 26 % of the area was in the farm holdings of 2.0 to 5.0 ha (22,178 ha); 10 % area was larger than 5.0 ha (8,076 ha). The total no. of farmers were 57,711 with 93.4% having less than 2 ha, 5.82% between 2 and 5 ha and 0.8% with greater than 5 ha.

Ancillary units such as feed mills, hatcheries and diagnostic labs have been developed to support in the industry, thus boosting regional and local economies even more. The number of hatcheries in 2006 were 191 in the state with a production capacity of 9,335 million PL per year and the number of feed mills was 25, PCR labs was 41 and LCMS-MS labs were 4 (MPEDA, 2006).

1.5.4 Employment generation

Shrimp farming is another avenue for generating employment opportunities andincreasing income of fishermen. A study conducted by CIBA (1996) reported that in Nellore District of Andhra Pradesh, employment increased by 2–15 percent after the establishment of shrimp farms, with a corresponding increase of 6–22 percent in income of farm labourers. According to the Fisheries Commissioner of Andhra Pradesh, scientific shrimp farming generates maximum employment opportunities of 650 man-days per ha per annum as against 225 man- days per ha per annum through other agricultural operations.

1.6 Study area - Krishna District, Andhra Pradesh

Krishna District in AP has been identified as study area and the N aCSA societies in the district have been identified to study the perceptions of climate change impacts and adaptation to shrimp farming. The area of Krishna district is 8727 sq. km and the length of the coastal line is 111 Km and continental shelf area is 865 sq.km. The districtis endowed with Kolleru lake, Upputeru and good number of fish and brackishwater resources for development of aquaculture. Out of 50 mandals in the district 10 mandals (Nagayalanka, Avanigadda, Koduru, Machilipatnam, Pedana, Bantumilli, Kruthivenu, Mudinepalli, Kalidindhi and Kaikalur) contributed to the development of shrimp farming in brackishwater. In Kolleru and surrounding areas viz., Kaikaluru, Mandavalli, Nandivada, Mudinepalli, Gudivada and Kalidindi mandals shrimp farming was done in freshwater areas. The potential area available in the district was 50,000 ha and the area developed was 36,143 ha with water spread area of 11,494 ha (MPEDA, 2006). About 15,000 ha has been abandoned in the district due to the disease problems, non-availability of electric supply lines, steep increase in production cost and also due to the volatility and loss of market prices. The farmers are not able to recover even the working capital amount spent and the profit margin is greatly reduced. The average size of aquaculture farms in the district is about 0.75 ha and 95% of the farmers cultivate less than 2 hectares (Fisheries Department Unpublished documentation). At the end of the 1990s, the development of aquaculture had come out of the control of the concerned governmental departments (Anonymous 2005) and resulted in the outbreak of diseases due to poor management practices. Despite increasing the inputs, shrimp yield decreased (Anonymous 2005; MPEDA 2006). The details of fisheries and aquaculture statistics for the period 2008-09 related to aquaculture are presented in Box 1.

Box 1. Fisheries and aquaculture statistics in Krishna District during 2008-09

Production details

Inland fish production	251312 MT
Marine fish production	16172 MT
Fresh water prawn production	11026 MT
Brackish water aquaculture production	5903 MT
Total fish and Prawn production	284413MT

Area and farmers details

	Brackishwater	Freshwater
No. of farmers	3236	7249
Water spread area (ha)	4063	20647
Utilized area (ha)	2580	5003

Size of farm holding	1-2ha
No. of Registered farms under CAA	2550

(Source:. Department of Fisheries, Krishna district (2008-09) Machilipatnam (Unpublished)

1.6.1 Shrimp farming systems and practices in Krishna District

Eighty per cent of shrimp farms are extensive and 10 per cent of shrimp farms are traditional type and 10 per cent of shrimp farms are modified extensive type in Krishna District. Almost all farmers cultivate tiger shrimp *Penaeus monodon*. However, very few farmers cultivate Indian white shrimp (*Fenneropenaeus indicus)*. There is a high prevalence of usage of water from agriculture canals and drains (>70%). Extensive farming system operates with low stocking density and lime and organic materials are used to stimulate production of natural food for their shrimp. In medium density semi-intensive system pond preparation was elaborate, with dry-out once or twice a year, tilling and liming, and fertilisation with nitrogen and phosphorus compounds to promote natural production. Various extra cellular enzyme preparations, probiotics and bacterial inocula are used to improve water quality, but the benefits of these treatments have not been conclusively established. 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, where 9 to 10 weeks after stocking the pond ecology shifts during the production cycle from an autotrophic phytoplankton-based community to a heterotrophic bacteria-based community. This shift improves water quality through fast digestion of organic waste and without production of toxic metabolites. Disease outbreak is the most feared threat to the shrimp aquaculture in the district, which started from 1994 onwards and the frequency of disease occurrence ranged from 2.7 to 8 crops out of 10 crops.

1.7 Climate change in the study area – Andhra Pradesh and Krishna District

Climate change is one of the most important global environmental challenges facing humanity with implications for food production, natural ecosystems, freshwater supply, health, etc. While a changing climate poses a challenge to humanity as a whole, the available evidence suggests that the developing countries particularly are more vulnerable. Climate change will seriously hit the agriculture sector in Andhra Pradesh (AP), affecting the incomes of farmers by as much as 20 per cent. According to the latest World Bank report on "The impact of climate change on India", dry land farmer's incomes in AP plunge by 20 per cent. Under a modest to harsh climate change scenario of a substantial rise in temperatures (2.3^0 C to 3.4^0 C) and a modest but erratic increase in rainfall (4% to 8%), small farmer incomes could decline by as much as 20%.

The east coast of India bordering the Bay of Bengal is a passive continental margin developed during separation of India from Antarctica in the Late Jurassic (Bastia and Nayak2006). Administratively, the 2,350-km-long east coast forms the eastern seaboard of three States—Orissa in the north, Andhra Pradesh in the centre, and Tamil Nadu in the south. The Pennar delta and Pulicat Lake are the dominant features along the coast south of the Krishna– Godavari delta region. Andhra Pradesh lies between 12°41' and 22°N latitude and 77° and84°40'E longitude, and is bordered by the south and Karnataka to the west. Andhra Pradesh is historically called the "*Rice Bowl of India*". More than 77% of its crop is rice. Geographically, Andhra Pradesh is composed of most of the eastern half of the Deccan plateau and the plains to the east of the Eastern Ghats. It is the fourth largest state in India. The coastal plains are, for a major part, delta regions formed by the rivers Godavari, Krishna, and Pennar. The Eastern Ghats are a major dividing line in the state's geography. Most of the coastal plains are put to intense agricultural use. West and South west parts of Andhra Pradesh have semi-arid conditions.

The climate of Andhra Pradesh varies considerably, depending on the geographical region. The major role in determining the climate of the state is played by monsoons. The summer season lasts from March to June. In the coastal plain the summer temperatures are generally higher than the rest of the state, with temperature ranging between 20°C and 41°C. July to September is the season for tropical rains in the state. The state receives heavy rainfall during these months. About one third of the total rainfall in Andhra Pradesh is brought by the North-East Monsoons. October and November see low-pressure systems and tropical cyclones formed in the Bay of Bengal which, along with the north-east monsoon, bring rains to the southern and coastal regions of the state. Winters in Andhra Pradesh are pleasant. November, December, January and February are the winter months in AP. Since the state has a long coastal belt the winters are not very cold in those regions. The range of winter temperature is generally 12°C to 30°C.

1.7.1 Precipitation

Approximately 70% of the total annual rainfall over the state is confined to the southwest monsoon season (June-September). Recent decades have exhibited decline in the number of rainy days along east coast (De and Mukhopadhyay, 1998; Singh and Sontakke, 2002). Due to this it is projected, the gross per capita freshwater availability in India will decline from about 1,820 m^3/yr in 2001 to as low as about 1,140 m^3/yr in 2050 (Gupta and Deshpande, 2004) and will reach a state of water stress before 2025 (CWC, 2001). The same trend can be observed in the state also. Some changes are taking place in the character of the monsoon. There is substantial decline in monsoon depressions and increase in low pressure systems. In 2000, Hyderabad witnessed 350 mm rainfall in a day when the yearly average is 700 mm (Source: www.tropmet.res.in) which led to flooding of the city. The lakes do not have capacity to hold this amount of water and it resulted in flooding of colonies and the loss of lives and property.

1.7.2 Temperature

Most of the observed increase in global average temperatures since the mid-twentieth century is very likely to be due to the observed increase in anthropogenic greenhouse gas concentrations (Rosenzweig et al., 2008). The predictions of climate change over India are increasing trends in annual mean temperature, warming more pronounced during post monsoon and winter, increase in frequency of hot days and multiple-day heat wave (Kripalani et al., 1996) and a similar trend was observed in AP state. Water and air temperatures are expected to rise during summer months and this will be more pronounced in southern states.

1.7.3 Extreme Weather Events

One of the most significant consequences of global warming would be an increase in magnitude and frequency of extreme events like heat waves (IPCC, 2007). Most of the available impact estimates however, do not account for impacts due to extreme climate events (ECEs) such as cyclones and droughts, whose frequency and intensity could also increase under the changed climatic conditions. These natural disasters currently cause significant damages in developing countries. The east coast of India is subject to frequent cyclonic storms and occasional tidal waves and studies conducted by CIBA revealed the extent of loss of aquaculture stock and damage to aquaculture facilities due to ECEs. Andhra Pradesh has had many weather related impacts in recent years such as the worst drought in 50 years occurred in early to mid 2009 followed by a severe flood of once in 100 years in October 2009. These extreme climatic events have had severe consequences including heavy economic losses to shrimp farmers in the State.

1.7.4 Cyclones

Andhra Pradesh has the longest coastline of all the states in the country. The AP coast is known for frequent tropical cyclones and associated floods and tidal surges causing loss of life and property in the region (Bastia and Nayak 2006). There is the risk of cyclones, the intensity of which is predicted to rise. The segment of Andhra Pradesh coast between Ongole and Machilipatnam is most vulnerable to high storm surges that have been a regular feature in the Bay of Bengal**.** In this century alone, the state has been pounded by 18 devastating storms causing enormous loss of life and property. The 1977 Diviseema Cyclone that was accompanied by a 5-m storm surge killed about 10,000 people and 0.2 million livestock besides causing enormous damage to property worth Rs. 175 millions in 2300 villages in the Krishna delta region. During 1996 the disaster cyclone accompanied by six-meter high tidal waves which hit the coast at Nellore -Prakasam-Konaseema has taken a toll of thousands of lives and at least 100 villages were washed away. Millions of acres of ready-to-harvest paddy and about five million coconut trees spread over an area of 1000 sq.km have been destroyed. (Source: http://www.envis.nic.in/soer/ap/cme_cyc_AP.htm).

1.7.5 Tsunami

The AP coast is also prone to tsunamis. Though tsunamis are not climate related, the impacts from these devastating events can be similar to some extreme climate events such as cyclonic tidal waves. During the 2004-tsunami although the coast of the southern state of Tamil Nadu was the most affected with tsunami inundation limits exceeding 800 m at some places (Chadha et al. 2005) killing about 10,000 people, the tsunami impacted the AP coast as well leading to loss of life and property at several locations, especially in the low lying zones along the Krishna and Godavari deltas (Nageswara Rao et al., 2007).

1.7.6 Drought

At least half of the severe failures of the Indian summer monsoon since 1871 have occurred during El Niño years (Webster et al. 1998). Consecutive droughts between 2000 and 2002 caused crop failures. The agriculture sector in Andhra Pradesh was worst hit by the 2002 drought. The area under food grains during 2002 was 30 percent less than the normal acreage covered by the crops. The production of rice decreased to such an extent that the state needed to import rice.

1.7.7 Heat waves

The four hottest years in Andhra Pradesh since 1901 have occurred in the last 10 years. The year 2002 was the warmest year in Andhra Pradesh on the record since 1901 followed by 2006, 2003 and 2007. During 2009 heat wave conditions also prevailed over parts of Coastal Andhra Pradesh during second fortnight of May. Even in October 2009, temperatures are soaring when there should be a chill in the air (Source: National Climate Centre, India Meteorological Department).

1.7.8 Sea level rise

Climate change and associated sea-level rise (SLR) is one of the major environmental concerns of today. Global mean sea-level has risen by about 0.1-0.2 mm yr^{-1} over the past 3,000 years and by 1-2 mm yr^{-1} since 1900, with a central value of 1.5 mm yr^{-1}. Global warming during the past few hundred years is likely to result in a sea level rise of up to half a meter, possibly more, by 2050 (Nicholls, 1998; Nicholls and Mimura, 1998; Nicholls and Lowe, 2004). Nicholls and Branson (1998) used the term "coastal squeeze" to describe the progressive loss and inundation of coastal habitats and natural features located between coastal defences and rising sea levels. The inter-tidal habitats will continue to disappear progressively, with adverse consequences for coastal biological productivity, biodiversity, and amenity value. An estimate by Nicholls et al. (1999) suggests that by the 2080s, sea-level rise could cause the loss of as much as 22% of the world's coastal wetlands. The total flood-prone area in India is about 40 m ha (Mirza and Ericksen, 1996).

The threat of rise in sea-levels as a result of changing climate makes the coastal resources, coastal infrastructure and population living in the coastal areas highly vulnerable. Rising sea levels, which could flood land (including agriculture and aquaculture) and cause damage to coastal infrastructure and other property, poses another threat. Beyond actual inundation, rising sea levels will also put millions of people at greater risk of flooding. Increased sea water percolation may further reduce fresh water supplies.

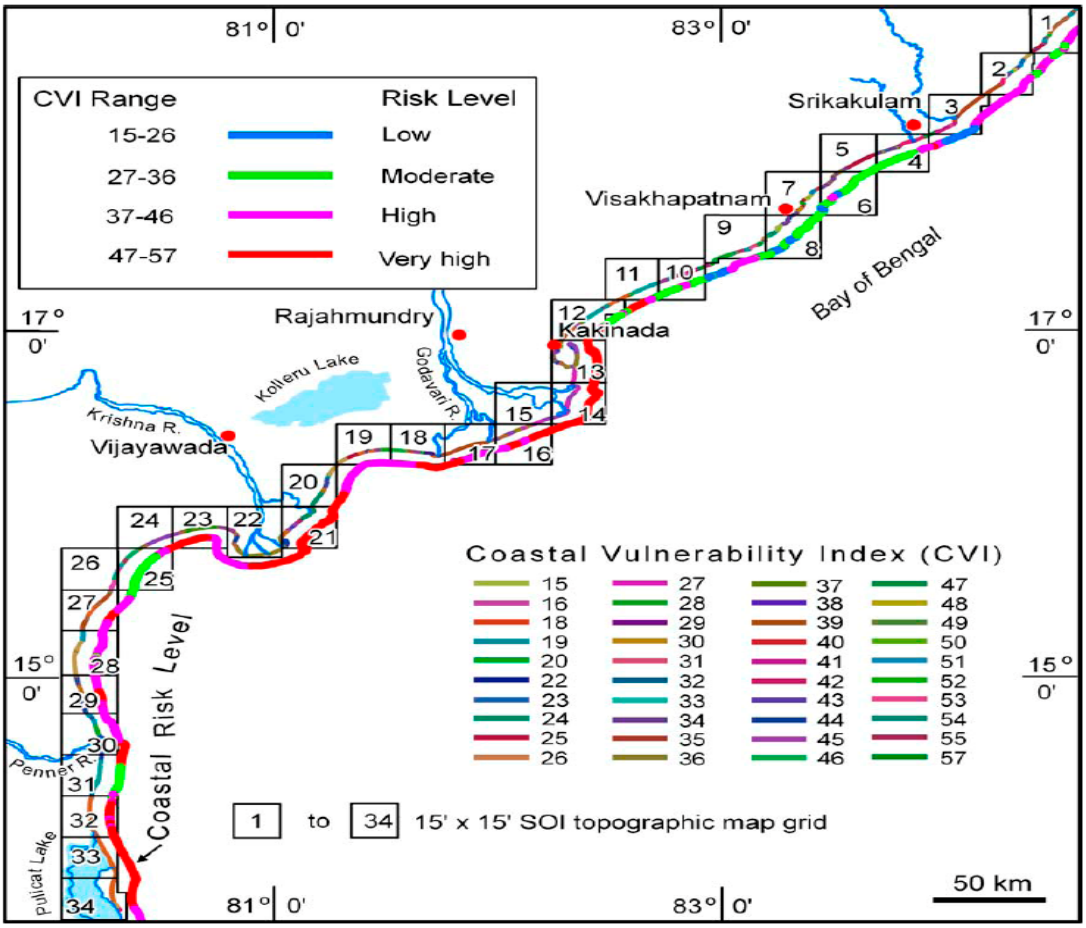
Sea levels are rising at a rate of about 1.0–1.75 mm per year along Indian coast due to global warming (Unnikrishnan et al. 2006; Unnikrishnan and Shankar 2007) as revealed by long-term tide-gauge data from various stations and corrections for vertical land movements. Pronounced erosion even along certain major depocentres like deltas of the east coast of India was mainly attributed to anthropogenic forcing (Baskaran, 2004; Hema Malini and Nageswara Rao, 2004; Nageswara Rao et al., 2008).

Vulnerability to sea level rise

The future sea-level rise is likely to further intensify the storm surges (Pendleton et al. 2004), besides accelerating shoreline erosion and other problems like seawater intrusion and damage to coastal structures, thereby making the AP coast much more vulnerable in future. About 43% (442.4 km) of the 1,030-km-long AP coast is under very high-risk (Krishna, Godavari and Pennar delta front coastal sectors which are very low-lying and almost flat with mudflats, mangrove swamps, and lagoons/backwaters) (Fig.3) Each colour of the coastline indicates a particular coastal vulnerability index (CVI) value from 15 to 57 (except for the CVI values 17, 21 and 56). The thick coloured parallel line all along the coast shows the risk levels of the coast based on the categorization of CVI values into four risk classes as per the classification scheme shown in the upper left legend in the figure. The black coloured squares along the coastline (from 1 to 34) represents the grid of SOI topographic maps.

Even the small tidal range in these areas can reach far inland since the gradient is extremely gentle. About 35% (363.7 km) are under high-risk (southern part of the AP coast near Pulicat Lake; north of Pennar delta; south of Krishna delta; and between Krishna and Godavari deltas in the central part of AP coast) if the sea level rises by ~0.6 m displacing more than 1.29 million people living within 2.0 m elevation in 282 villages in the region (Nageswara Rao et al., 2008). In the remaining part, 193.9-km-long coast (19% of the total) mainly the non-deltaic dune-front sections, come under moderate-risk category, while the rocky coast on both sides of Visakhapatnam and some embayed/indented sectors over a combined length of 30 km (3%) are in the low-risk category. No part of the Krishna–Godavari delta coast is in the low or moderate risk levels. If the sea level rises by 0.59 m as predicted by 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. The new spring high tide reaches further inland by another ~0.6 m above its present level of 1.5 m, i.e., up to 2.1 m. In such a case, an additional area of about 1,233 km^2 along the AP coast including 894 km^2 in the Krishna and Godavari delta region alone would go under the new inter-tidal zone thereby directly displacing about 1.29 million people (according to 2001 census) who live in 282 villages spread over nine coastal districts of Andhra Pradesh. Notably, the inhabitants of these villages are mainly hut-dwelling fishing communities who are highly vulnerable in socio-economic terms as well. Further, there is every possibility of increased storm surges (Unnikrishnan et al; 2006) reaching much inland than at present with the rise in sea level.

The variations in the annual and monthly average high tide and low tide in the study area for 30 years during (1980-2009) are depicted in Fig.4. The maximum high tide was registered in the month of October followed by November and December and monthly low tide was recorded in the month of March followed by February and April. Annual average maximum high tide was registered in the year of 1980 followed by 1997 and 1993 and the annual average low tide was recorded in the year 1998 followed by 1995 and 1997.



Souce: Nageswara Rao et al. (2008)

Fig. 3 Coastal vulnerability index (CVI) and risk levels of different segments of AP coast.

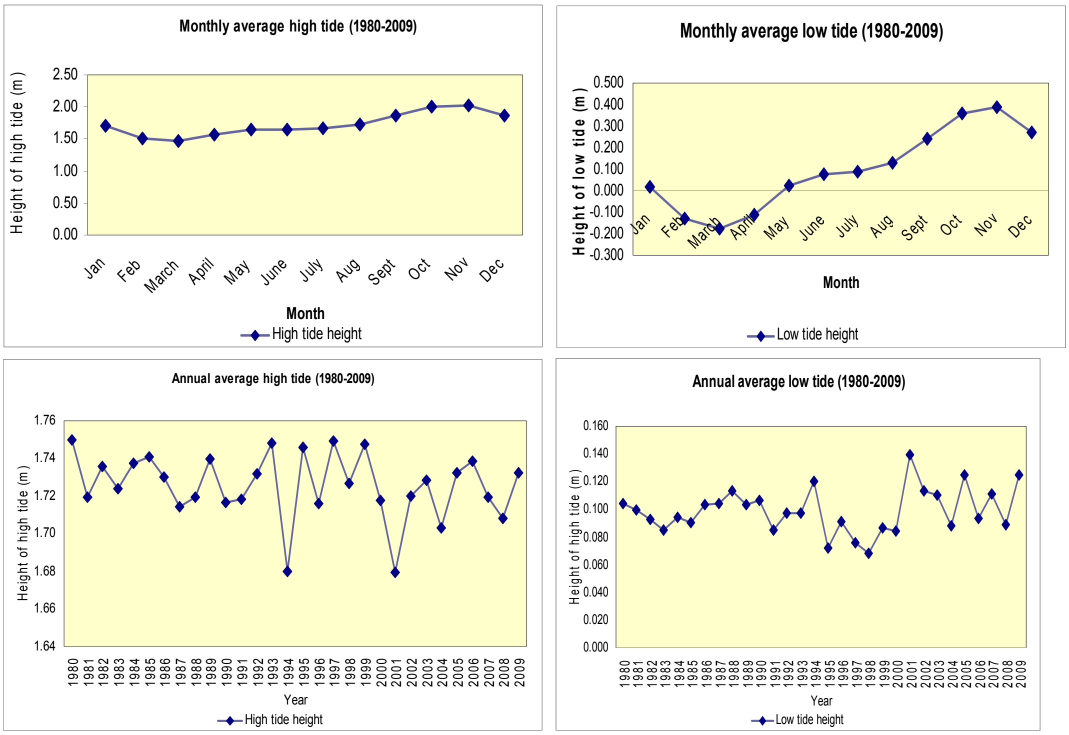
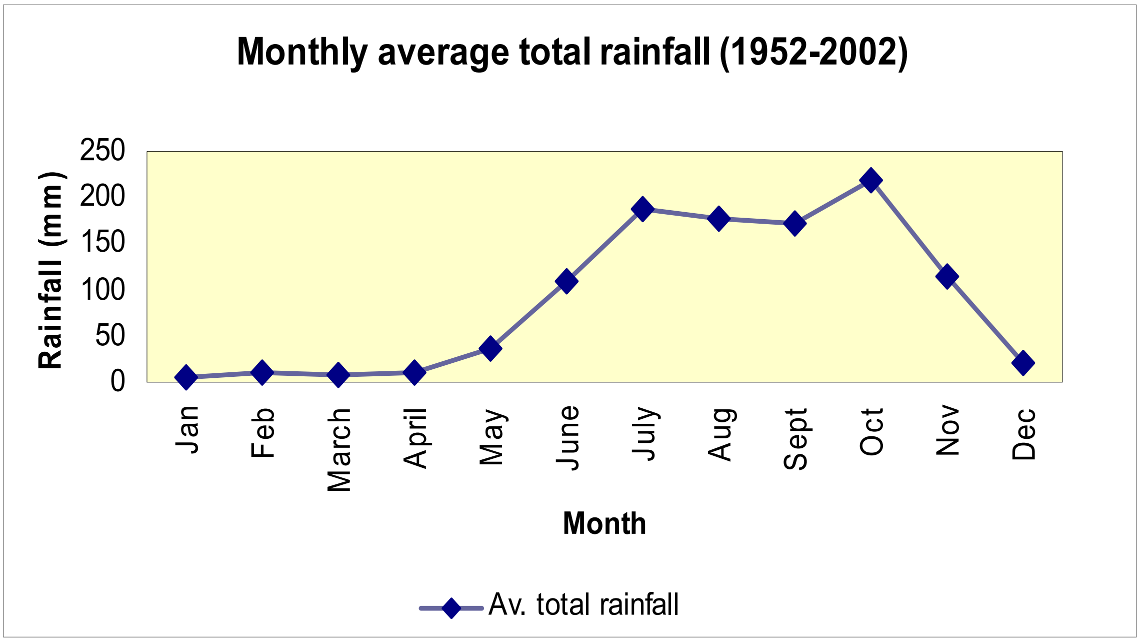


Fig.4. Variation in annual and monthly average high and low tides in the study area

1.8 Climate in Krishna District

The climate in Krishna district is summer in March to June, rainy season (southwest monsoon), winter during November to January. Recently the temperatures registered in summer are very high and as high as 50^{0}C was recorded during 2007 in IMD Observatory located at Gannavaram. The climate normals in the district based on the weather parameter values from 1950 to 1980 are given in Annexure-I

The variations in the average annual and monthly total rainfall for 50 years from 1952-2002 is shown in Fig.5. The rainfall was high in the month of October followed by July. The rainfall was low during the months of January to April. Ultimately, the annual average total rainfall . Annual average rainfall was high in the year 1994 followed by 1956 and 1962. Lowest amount of rainfall was recorded in the year of 1984 followed by 1965, 1971 and 1993.



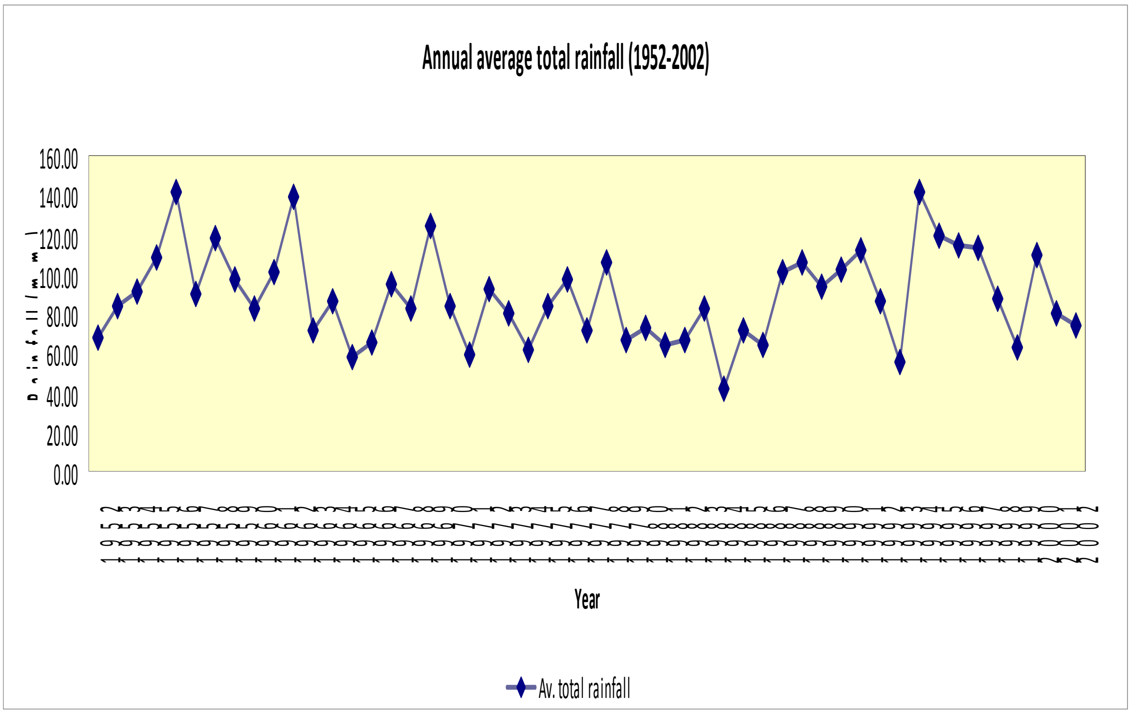
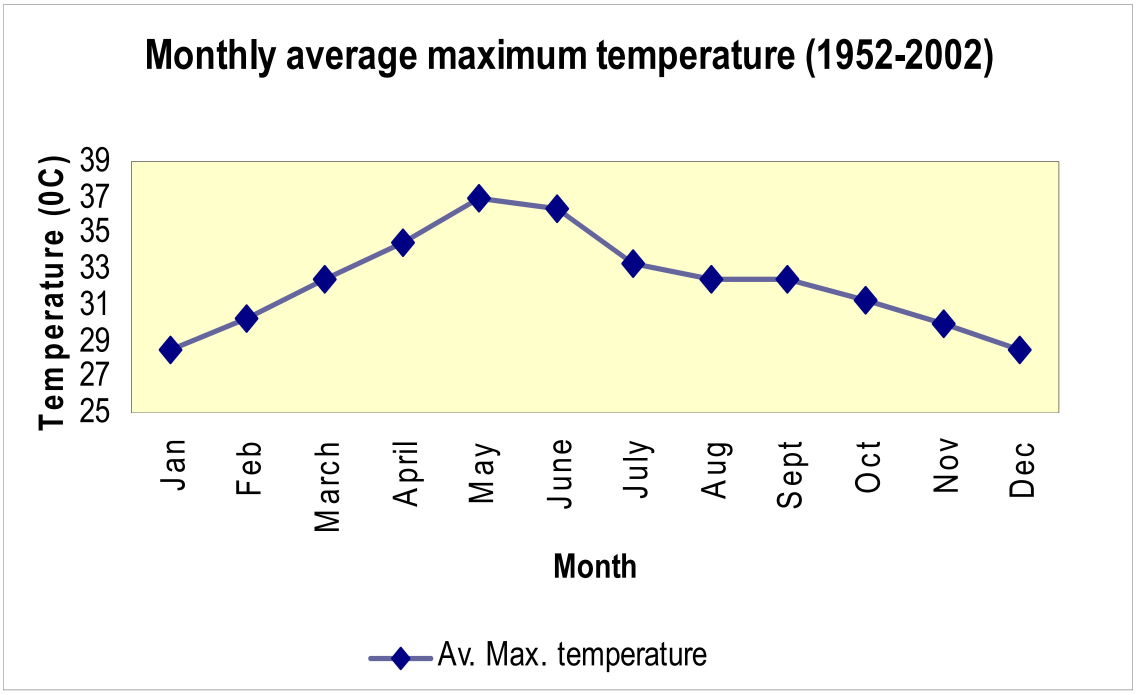


Fig.5. Variation in annual and monthly total rainfall in the study area

The variations in average monthly maximum and minimum temperature for 50 years during 1952-2002 are depicted in Fig.6. The maximum temperature was registered in the month of May followed by June and April. Minimum temperature was recorded in the month of December followed by January and February.



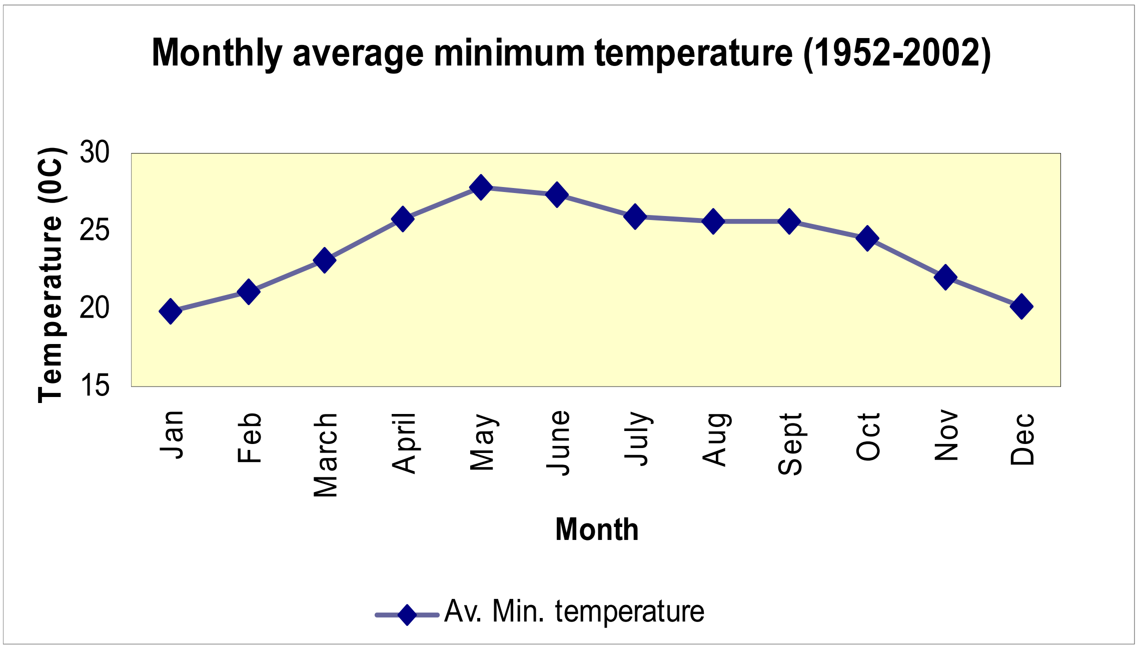


Fig.6 Variations in monthly average maximum and minimum temperatures in the study area.

2. Farmer's perception of climate change

The farmer's perception on climate change and impacts on shrimp farming, economic impacts, climatic events risk assessment and seasonal and crop calendar are presented in this chapter for both inland and coastal shrimp farming areas in the study area.

2.1 Inland shrimp farming area (Chinnapuram)

In the FGD meeting conducted at Chinnapuram (Inland shrimp farming area), the responses of 16 farmers representing different NaCSA societies and non-society was obtained. The results of farmer's perceptions on climate change, economic impacts and adaptation measures to be followed and the agencies to help them and the time line for implementation in inland shrimp farming area are presented in Table 1.

The climate change events identified on priority were seasonal changes, heavy rains, floods and cyclone by 13, 10, 8 and 7 farmers respectively. The seasonal changes were mainly temperature variations and delay in monsoon. The water inundation in ponds is due to heavy rainfall caused by both cyclones and floods and the impacts are same in both the cases.

Fig.7. Focus group discussion process at Chinnapuram, Inland shrimp farming area

Table 1. Results of farmer's focus group discussion conducted at Chinnapuram (Inland shrimp farming area)

Climate Change Event	Impacts (I)	Risks	Economic loss
A. Heavy/ Torrential Rain	I1. Salinity reduction I2. p^H fluctuations I3. Reduced dissolved oxygen	I1, I2 & I3. • Reduced molting & • Disease outbreak	I1, I2 & I3. • 70% loss in summer crop if it occurs on or above 80 days of culture. • 50% loss in monsoon crop if it occurs on or above 80 days of Culture.
	I4. Breach of pond dykes I5.Submergence of ponds I6. Damage to farm shed	I4, I5 & I6. Infrastructure damage	I4, I5 & I6. Rs.25000 – 50,000/ha for repairing dykes and ponds.
	I7. Damage to. electricity lines & power failure I8. Difficulty in access to shrimp ponds	I7 & I8. High Cost of production per kg of shrimp	I7 & I8. Rs.17,500 to Rs.30,000/ha extra electricity charges
Seasonal Variations	I1. High salinity I2. High pond water temperature I3. Reduced Dissolved Oxygen	I1, I2 & I3 • Retarded growth & • Low productivity	I1, I2 & I3 Loss of income • At 40 DoC – 100% loss • At 80 Doc – 50% loss • At 120 Doc – 10% loss
	I4. Delaying of crop planning /season	I4. Low productivity	I4. Loss of income
	I5. Temperature fluctuations I6. Low feed intake I7. Stress to the animal	I5, I6 & I7 • Molting problem & Slow growth • Low production	I5, I6 & I7 • Loss of income up to 25%
Floods	I1. Death of shrimps (due to rapid oxygen depletion) I2. Escape of the shrimps due to breaching of ponds I3. Occurrence of diseases	I1, I2 & I3 • Loss of stock • Low production	I5, I6 & I7 • 70-100% loss
	I4. Submergence of ponds I5. Breach of pond dykes & sluice	I4, I5, I6 & I7 • Severe damage to infrastructure	I4, I5, I6 & I7 • Rs.60,000/ha loss
	I6. Damage to electricity lines & power failure I7. Loss of human life & Livelihood		
Cyclones	I1. Damage to electricity lines & power failure I2. Loss of human life & livelihood I3. Vanishing of shrimp stock I4.Contamination across the ponds I5. Loss of farm infrastructure	I1 to I5 • Lack of access to farm site & ponds • Loss of life, livelihood & property	I1 to I5 • 100% loss of livelihood

Note: Impacts are denoted as I1, I2, I3…. and so on and other columns are referred to these impacts.

2.1.1 Risk Analysis

The likelihood and consequence ratings (rounded off to lower number) of extreme events identified by the farmers in inland area is presented in Table 2. Based on the actual total risk score obtained without rounding the figures, the climatic extremes were ranked in priority as flood (19.20), seasonal changes (18.71) heavy rain (14.79) and cyclones (13.92).

Table 2. Likelihood and consequence ratings of extreme events observed in inland area (Chinnapuram)

Change/Risk	Consequence (C)	Likelihood (L)	Total Risk score (CxL)	Risk ranking
Flooding	4.23	4.54	19.20	1
Seasonal change	4.77	3.92	18.71	2
Heavy rain	3.92	3.77	14.79	3
Cyclone	3.77	3.69	13.92	4

The likelihood and consequence ratings were plotted in a matrix table to arrive at the risk priority level for each extreme event. It was observed that floods and seasonal changes are under extreme risk category, whereas heavy rain and cyclone are under high risk category (Table 3).

Table 3. Risk priority matrix of extreme events in inland area (Chinnapuram)

Consequence / Likelihood	1. Insignificant	2. Minor	3. Moderate	4. Major	5. Catastrophic
5.Almost certain				**Flood**	
4. Likely				**Heavy rain, cyclone**	**Seasonal change**
3. Possible					
2. Unlikely					
1. Rare					

E	**H**	**M**	**L**

2.1.2 Seasonal and crop calendar

The details of changes in seasons and crop activities with respect to weather changes over a period of one year are presented in Table 4. Rainy season is from June to September with more rains in July and August months. Dry season is from January to May with more magnitude in March, April and May during which hot wind flows were more. Cold season is from December to February and it is colder is in the last two months. Occurrence of cyclones and hot wind flows is unusual.

Crop activities such as pond preparation including repair of pond dykes, water intake and sluice structures, draining and drying the ponds were taken in the dry months January/ February for the first crop and June/July for the second crop. During this time the weather is dry and allows the pond bottom to dry faster. Water filling and bloom development is during February and March for the first crop and July to September for the second crop. Stocking of the seed for the first and second crops is during February to March and July to September, respectively. The harvesting time spreads over May to June for the first crop and November to December for the second crop. Diseases were more during monsoon and post monsoon period. Hence in most of the areas second crop was not a successful one. The production, fry price and market prices (for harvested shrimp) were also high during the first crop compared to second crop.

Table 4 . Seasonal and crop calendar activities of Inland shrimp farming area

Seasonal calendar												
	Jan	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Rainy season						R	R++	R++	R			
Dry season	D	D	D++	D++	D+++							
cold winter	C++	C+										C
Hot			H+	H++	H+++							
Cyclones											Cy	
SW monsoon						SW++	SW++	SW	SW			
NE monsoon											NE	
Hot wind flow			W++	W++								
Unusual												
Crop calendar												
Activities	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Pond preparation	P	P				P	P					
Drying	D					D						D
Water colouring (plankton growth)		WC	WC				WC	WC	WC			
Stocking		S	S				S	S	S			
Harvesting					H	H					H	H
Diseases						D	D	D	D	D	D	D
Repair	R	R				R	R					R
Production price* (H/M/L)	M	M	H	H	HH	HH	L	L	L	L	L	L
Fry Price (PL)	+++	+++	+++	+++	+++	-	- -	- - -	+	++	+	
Market Price	++		+++	+++	+++	-	-	- -	- -	-	++	++

+ = increasing magnitude and high units - = decreasing magnitude and low units

* L –Low, M- Medium, H-High

2.2 Coastal shrimp farming area (Gullalamoda)

In the FGD meeting conducted at Gullalamoda (coastal shrimp farming area), the responses of 17 farmers, some farmers from different societies of NaCSA and some non-society farmers was obtained. The farmer's perceptions on climate change, impacts on shrimp farming, economic impacts and adaptation measures to be followed and the agencies to help them and the time line for implementation are presented in Table 5.

The climate change events identified by priority were high temperature, floods, low/un- seasonal rain fall, low temperature, cyclone and low tidal amplitude by 15, 13, 10, 9, 7 and 7 farmers respectively. The water inundation in ponds is due to both heavy rainfall and floods. Cyclones are not a problem as they are not a very frequent event. However, if cyclone occurred with heavy rainfall, then the economic loss was hundred per cent.


Fig.8 Focus group discussion process at Gullalamoda, coastal shrimp farming area

2.2.1 Risk Analysis

The likelihood and consequence ratings (rounded off to lower number) of extreme events identified by the farmers in coastal area are presented in Table 6. Based on the actual total risk score obtained without rounding the figures, the extreme were ranked in the order of priority as high temperature (15), flooding (12.25), low rainfall (11), less cyclone (8.75), low tidal movement (8.5) and low temperature (7.25).

Table 5. Results of farmer's focus group discussion (coastal shrimp farming area) conducted at Gullalamoda

Climate Change	Impacts (I)	Risks	Economic loss
High temp	I.1 Increase in pH levels I.2 Increase in salinity I.3 Low water availability	I1, I2 & I3. • Low growth rates • Increase in culture period • Loose shell syndrome (LSS) • Reduced market • Increased cost of production	I1, I2 & I3. • Shrimps die and 90% loss
Low/ un-seasonal rain fall	I.1 Increase in salinity I.2 Low water availability	I.1 • Favours culture up to someextent and further increase leads to economic loss I.1 & I.2 • Low growth rates • LSS • Reduced market, Increasedcost of production	I.1 & I.2 • Rs. 5000/- loss due by 30 days increase in culture period
Floods	I.1 Water pollution I.2 Increase in viral infections I.3 Damage to dykes I.4 Damage to farm buildings and feed stock	I.1 & I.2 • Leads to diseases I.3 & I.4 • Infrastructure damage	I.1 & I.2 • 50% loss due to viral infections I.3 & I.4 • 100% stock escapefrom ponds nearer to water source
Low Temperature	I.1 Increase in viral/ bacterial infections and increased virulence	I.1 Leads to diseases	I.1 Rs. 10000/- loss per acre
Cyclone	I.1 Safe culture with normal rain fall I.2 If cyclone with heavy rainfall – leads to flooding	I.1 Good profit no loss I.2 - I.1 to I.4 points under floods	I.2 • If cyclone - 100% loss I.2 - I.1 to I.4 points under floods
Low tidal Amplitude	I.1 Decreased water level due to non-availability of water for pumping	I.1 Shrimps under stress	I.1 Shrimp die - 25% loss

Note: Impacts are denoted as I1, I2, I3…. and so on and other columns are referred to these impacts

Table 6. Likelihood and consequence ratings of extreme events observed in coastal shrimp farming area (Gullalamoda).

Change/Risk	Consequence(C)	Likelihood(L)	Risk score(CxL)	Risk ranking
High temperature	4.0	3.75	15	1
Flood	2.5	4.75	12.25	2
Low rainfall	3.50	3.00	11	3
Cyclone	3.00	2.75	8.75	4
Low tidal movement	3.75	2	8.5	5
Low temperature	3.50	2.25	7.25	6

The likelihood and consequence ratings were plotted in a matrix table to arrive at the risk priority level for each extreme event. It was observed that flooding, high temperature and low rainfall were in a high risk category. Less cyclone, low rainfall and low temperature were in medium risk category (Table 7).

Table 7. Risk priority matrix of extreme events in coastal shrimp farming area (Gullalamoda)

Consequence / Likelihood	1. Insignificant	2. Minor	3. Moderate	4. Major	5. Catastrophic
5.Almost certain			**Flood**		
4. Likely				**High temperature**	
3. Possible			**Cyclone**	**Low rainfall**	
2. Unlikely				**Low tidal movement, Low temperature**	
1. Rare					

	Extreme		High		Medium		Low

2.2.2 Seasonal and crop Calendar

The details of changes in seasons and crop activities with respect to weather changes over a period of one year are presented in Table 8. The summer season is from March to June with more temperatures in April and May. Winter season is from November to January and the maximum cold is in the month of January. Very high temperatures are observed during May and June and the lowest temperatures during December and January. There are no or low rains in the month of September. The occurrence of floods, cyclones and high tides are of unusual occurrence in the months of May and November.

Table 8. Seasonal changes and crop calendar activities in coastal shrimp farming area

Seasonal Calendar												
Weather /climate change	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Summer			S	S+	S++	S						
Winter	W++										W	W+
Rainy Season						R	R++	R	R			
High Temp				HT	HT++	HT+						
Low Temp	LT+											LT
Flood					F						F	
Low rain									LR			
Cyclone					Cy						Cy	
Tidal Movement					TM+						TM+	

Crop Calendar												
Activity	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Crop plan meeting	*											*
Pond drying	*,#	*,#						#				
Pond preparation	*,#	*,#	*,#					#				
Hatchery visit	*	*										
Water Pumping		*, #	*, #					#				
Seed stocking		*, #	*, #					#				
Harvesting	#					*, #	*, #					#
Crop Running	↔			↔							↔	

* NaCSA societies # Non- Societies

\+ = Increasing magnitude

Crop planning meetings were done only in societies in December and January months before the first crop and these meetings were not serious for the second crop as many of the farmers are not taking *second* crop. The first crop is from February/March to June/July and the second crop is from Aug/Sept to December/January. Crop activities such as pond drying for the first crop are in January and February during which the weather is normally dry and without rains and for the second crop this activity is in the month of August. The society farmers will visit the hatcheries in advance during January/February to get quality seed. Water pumping and seed stocking operations for the first crop are in February/March and for the second crop during August. Pond preparation including repair of pond dykes, intake water and sluice structures, and ploughing are taken in the dry months January and February for the first crop and August for the second crop. The harvesting time spreads over June/July for the first crop and December /January for the second crop.

3. Stakeholder and Institutional mapping and analysis

Stakeholder analysis is the identification of a sector's key stakeholders, an assessment of their interests, and influence and importance. Stakeholder analysis contributes to project design through the logical framework, and by helping to identify the most important stakeholders to target for implementing adaptation measures.

The identified stakeholder is any person or organization, who can be positively or negatively impacted by climate change in milkfish pond farming sector or had the significant influence on adaptations towards the problems (Table 9) Stakeholders are persons, groups or institutions involved in a sector. This definition of stakeholders includes both winners and losers, and those involved or excluded from decision-making processes.

Types of stakeholders are:

- **Primary stakeholders** : are those ultimately affected, either positively or negatively by milkfish production.
- **Secondary stakeholders** : are the 'upstream or downstream stakeholders or service providers', that is, persons or organizations who are indirectly affected by milkfish production.
- **Key stakeholders** : are those who can significantly influence, or are important to the success of the project in terms of the project's priority policy objectives and project purpose.

The results of stakeholder mapping including characterization and classification of key stakeholders and their tasks towards tiger shrimp farming and climate change are presented in this section. The stakeholders were classified by the expert judgment group into levels of importance and influence into grades from 1 very low to 5 very high.

A stakeholder is any person or organization, who can be positively or negatively impacted by climate Change. The list of different stakeholders in shrimp aquaculture sector is shown in Table 9.

Table 9. Identification of stakeholders on tiger shrimp pond farming

Upstream	Production	Downstream
Brood stock gatherers	Care taker	Broodstock mediator
Hatchery PL producers	Owner operator	Shrimp wholesalers
Nauplii producers	Absentee landlord	Shrimp processors
Feed manufacturers	Service	Ice suppliers
Fertiliser suppliers	Private service providers	Transporters
Other input suppliers	Government service suppliers	Exporters
	Academic service suppliers	

3.1 Stakeholder influence

A stakeholder's degree of influence translates into the relative power they have over tiger shrimp farming as well as the degree to which they can help desired changes to be implemented or blocked. In broad terms, a stakeholder's influence derives from their economic, social or political position, or their position in the hierarchy. Other forms of influence may be more informal (for example, personal connections to ruling politicians).

3.2 Stakeholder importance

Importance is distinct from influence. There will often be stakeholders, especially unorganised primary stakeholders, upon which the project places great priority (eg. caretakers, owner operators, etc). Importance indicates the priority given to satisfying stakeholders' needs and interests through the project (Table 10).

Table 10. Assessment of stakeholder importance and influence

Stakeholder	Importance	Influence
Caretaker or manager	5	3
Nursery operator	5	3
Shrimp wholesaler	3	3
Feed manufacturer	3.5	3.5
Shrimp trader	2.5	2.5
Shrimp broker	2.5	2.5
Chemical/medication supplier	2	2

Stakeholders can then be classified into different categories which helps to identify key stakeholders to target with adaptation measures.

3.2.1 Stakeholders with low importance and low influence

Stakeholders with low influence and low importance and so are considered low priority to develop adaptation measures for or low ability to implement the adaptation measures such as chemical and medication suppliers, shrimp traders and shrimp brokers.

3.2.2 Stakeholders with high importance but low influence

Stakeholders of high importance but low influence indicate that they will require special initiatives if their interests are to be protected such as fry gatherers and fry dealers.

3.2.3 Stakeholders with low importance but high influence

Stakeholders with high influence, who can therefore affect the implementation of adaptive measures, but have low interest in shrimp production. This implies that these stakeholders may be a source of significant risk, and they will need careful monitoring and management such as local policy makers.

3.2.4 Stakeholders with high importance and high influence

Stakeholders appearing to have a high degree of influence on the project, who are also of high importance for its success. These are the key stakeholders that adaptation measures should be developed for. Key stakeholders were therefore identified as

- **Farm owner operators**. These are stakeholders that are most affected by climate change impact on productivity and profitability.
- **Feed and fertiliser manufacturers**. These stakeholders are important as they can provide credit and technical advice to the farmers.
- **Farm caretakers**. The care takers are the stakeholders who manage the ponds on a day to day basis so better management practices should be aimed and implemented by them.
- **Shrimp wholesalers**. Fish wholesalers can also provide credit to pond operators and have a great influence on the profitability of the farm operation.

3.3 Institutional mapping and analysis

Institutions play a critical role in supporting or constraining people's capacity to adapt to climate change. In order to better understand which institutions are most important to people in the target communities, an institutional mapping exercise is useful. The institutional analysis provides useful in identifying the institutions that should be engaged in the adaptation process, as well as potential allies and opponents in addressing vulnerability at the local level.

The institution is any organization that can be positively or negatively impacted by climate change in tiger shrimp pond farming sector or had the significant influence on adaptations towards the problems. The Institutions were classified by the expert judgment group into levels of importance and influence into grades from 1 very low to 5 very high (Table 11).

Table 11. Assessment of Institution importance and influence for shrimp culture

Institution	Importance	Influence
MPEDA Regional Offices	5	5
MPEDA Central Office	4.5	5
Coastal Aquaculture Authority	5	3
NaCSA	4	4
Department of Fisheries	4	5
CIBA	4	4
Regional Fisheries Training Centres (State level)	4	3
National Fisheries Development Board	3	2

3.3.1 Institution influence

Influence is the power institutions have over a sector to control what decisions are made, facilitate its implementation, or exert influence which affects the sector positively or negatively. Influence is perhaps best understood as the extent to which institutions are able to persuade or coerce others into making decisions, and following certain courses of action.

Power may derive from the nature of an institution, or their position in relation to other institutions (for example, line ministries which control budgets and other departments).
An institution's degree of influence translates into the relative power they have over tiger shrimp farming as well as the degree to which they can help desired changes to be implemented or funded or to which extent they can block changes. The Institution's influence derives from their political position and funds available.

3.3.2 Institution importance

An institution's level of importance indicates the extent to which an adaptations would be ineffective if they were not taken into account.

3.4 Stakeholder mapping

The categorised list of 'highest priority' stakeholders after initial analysis is shown at column 1 in ANNEXURE-III Farmers, hatchery operators, Input and feed dealers, broodstcok collectors, NGOs - National Association of Fishermen (NAF), Society of Aquaculture Professionals (SAP), Govt. organizations - The Marine Products Export Development Authority (MPEDA), National Centre for Sustainable Aquaculture (NaCSA), National Fisheries Development Board (NFDB), Coastal Aquaculture Authority (CAA), Indian Meteorological Department (IMD), Central Water Commission (CWC), Departments of Fisheries, Agriculture and Irrigation, College of Fisheries (CoF), Research Institutes -, Central Institute of Brackishwater Aquaculture (CIBA) Central Institute of Freshwater Aquaculture (CIFA), Central Institute of Fisheries Education (CIFE), SIFT (State Institute of Fisheries Technology), Krishi Vignan Kendra (KVK) and Research Station of Acharya NG Ranga Agricultural University (ANGARU), National Institute of hydrology (NIH), credit Institutions - Indian Bank (Lead Bank in the District), State Bank of India and Andhra Bank are the key stakeholders involved in the shrimp farming sector and climate change. The identified stakeholder is any person or organization, who can be positively or negatively impacted by climate change in shrimp farming sector or had the significant influence on adaptations towards the problems.

3.5 Stakeholder characteristics and classification

The stakeholders characteristics such as type (beneficiaries or implementers or financing agents or decision makers at National/State/local level), description (farmer/Govt./Research Institutions/Private organisations/NGOs), level of stake held in adaptation of shrimp farming to CC (primary/secondary/tertiary), their interest and influence over CC adaptation (very low, low, moderate, high, very high), the knowledge towards CC problems of shrimp farming, required actions to support the shrimp farmers for CC adaptation and the resources at their disposal for assistance of shrimp farmers adaptation to CC are presented in ANNEXURE-II. Primary stakeholders are those ultimately affected, either positively or negatively by CC actions. Secondary stakeholders are the 'intermediaries', that is, persons or organizations who are indirectly affected by the CC actions.

3.6 Institutional mapping

Different institutes involved in shrimp aquaculture sector and their brief role is given below.

3.6.1 Central Institute of Brackishwater Aquaculture (CIBA)

CIBA is an R&D institute under ICAR to conduct research for development of techno-economically viable and sustainable culture systems for finfish and shellfish in brackishwater. It act as a repository of information on brackishwater fishery resources with a systematic database also undertake transfer of technology through training, education and extension programmes and provide consultancy service.

3.6.2 Marine Products Export Development Authority (MPEDA)

The MPEDA role is envisaged under the statute is comprehensive - covering fisheries of all kinds, increasing exports, specifying standards, processing, marketing, extension and training in various aspects of the industry

3.6.3 Coastal Aquaculture Authority (CAA)

The CAA is regulatory body under Ministry of Agriculture and exercise the following powers and perform the following functions: Makes regulations for the construction and operation of aquaculture farms within the coastal areas; Inspects coastal aquaculture farms with a view to ascertaining their environmental impact caused by coastal aquaculture; Register coastal aquaculture farms; Order removal or demolition of any coastal aquaculture farms which is causing pollution after hearing the occupier of the farm; and To enter on any coastal aquaculture land, pond, pen or enclosure and make any inspection, survey, measurement, valuation or inquiry; remove or demolish any structure therein; and do such other acts or things as may be prescribed ; Perform such other functions as may be prescribed.

3.6.4 National Centre for Sustainable Aquaculture (NaCSA)

The initiative on implementation of BMPs was established under a cooperative program between the MPEDA and Network of Aquaculture Centres in Asia-Pacific (NACA). Later, it has also lead to policy and institutional change within India, culminating in the formation of the National Centre for Sustainable Aquaculture (NaCSA). NaCSA will facilitate links between aquaculture stakeholders and strengthen farmer societies, and farmers to facilitate formulation of common policies, strategies and voluntary guidelines to benefit farming community as a whole in the country. The main objectives of NaCSA are Promoting BMPs to improve aquaculture productivity and profits, capacity-building and empowerment of primary producers, Facilitating improved service provision, connecting farmers to markets to receive a better price for quality product, Technology transfer and diversification to other commercially important species, supporting improved food security and sustainable livelihoods in aquaculture communities.

3.6.5 National Fisheries Development Board (NFDB)

NFDB is looks at development of intensive aquaculture in ponds and tanks of fisheries development in reservoirs, coastal Aquaculture, mariculture, seaweed cultivation, infrastructure: Fishing harbours and landing centres, fish dressing centres and solar drying of fish, domestic marketing, technology upgradation, deep sea fishing and tuna Processing and Other Activities. It provides funding programme, training and research projects for over all department of fisheries and aquaculture sector.

3.6.6 Department of Fisheries Andhra Pradesh (DoF)

The important objectives are to increase of fish production and ensure sustainable development, development of fisheries value chain and boost exports, promote investment to create infrastructure and to Promote welfare of fishers and set up institutions to build skills of farmers.

3.6.7 Society for Aquaculture Professionals (SAP)

NGO's of Society of Aquaculture Professionals helps aquaculture professionals advance the art science and practice of aquaculture by providing opportunities for continuous professional development of individuals and being the voice of professionals to all stakeholders in the aquaculture industry

3.6.8 India Metrological Department (IMD)

IMD takes meteorological observations and provides current and forecast meteorological information for optimum operation of weather-sensitive activities like agriculture and allied sectors irrigation, shipping, aviation, offshore oil explorations, etc. Gives warning against severe weather phenomena like tropical cyclones, dust storms, heavy rains and snow, cold and heat waves, etc., which cause destruction of life and property. It provides meteorological statistics required for agriculture, water resource management, industries, oil exploration and other nation-building activities. It also conducts and promote research in meteorology and allied disciplines.

3.6.9 Central Water Commission (CWC)

CWC is charged with the general responsibility of initiating, coordinating and furthering in consultation with the State Governments concerned, schemes for the control, conservation and utilization of water resources in the respective State for the purpose of flood management, irrigation, drinking water supply and water power generation. The major responsible of CWC's are to carry out Techno-economic appraisal of Irrigation, flood control & multipurpose projects proposed by the State Governments, to collect, compile, publish and analyze the hydrological and hydrological data relating to major rivers in the country, consisting of rainfall, runoff and temperature, etc. and to act as the central bureau of information in respect of these matters; to collect, maintain and publish statistical data relating to water resources and its utilization including quality of water throughout India and to act as the central bureau of information relating to water resources; and to provide flood forecasting services to all major flood prone inter-state river basins of India through a network of 175 flood forecasting stations.

3.6.10 National Disaster Management Authority (NDMA)

NDMA lays down the policies, plans and guidelines for disaster management to ensure timely and effective response to disasters responsibilities are lay down policies on disaster management ;approve plans prepared by the Ministries or Departments of the Government of India in accordance with the National Plan; lay down guidelines to be followed by the different Ministries or Departments of the Government of India for the Purpose of integrating the measures for prevention of disaster or the mitigation of its effects in their development plans and projects; coordinate the enforcement and implementation of the policy and plan for disaster management; Recommend provision of funds for the purpose of mitigation;

3.6.11 National Centre for Disaster Management (NIDM)

National Centre for Disaster Management is responsible for 'planning and promoting training and research in the area of disaster management, documentation and development of national level information base relating to disaster management policies, prevention mechanisms and mitigation measures.

3.6.12 National Institute of Hydrology (NIH)

NIH is undertaking, aiding, promoting and coordinating systematic and scientific work in all aspects of hydrology.

3.7 Stakeholder task analysis

Stakeholder task analysis will help in developing cooperation between the stakeholder and the project team for the successful outcomes for the project. The tasks of all the identified stakeholders related to shrimp farming and climate change such as the role they play in shrimp farming sector, financial, technical and research support, natural resources and aquaculture policy management, and collection/ maintenance/ dissemination of data are presented in ANNEXURE-III.

3.8 Stakeholder Workshop –Stakeholder perceptions and adaptive measures

Identified stake holders participated in the stakeholder workshop organised at Vijayawada on December 2, 2009. The workshop discussed adaptation measures in three key themes: farmer adaptation measures, scientific/technical adaptation measures and institutional/policy adaptation measures in farmers, scientists and policy group respectively.

4. Climate change impacts and vulnerability

Vulnerability is a function of exposure, that is, the character, magnitude, and rate of climate variation to which a system is exposed and its sensitivity to exposure. The latter is the extent the system changes under the exposure and its adaptive capacity. Vulnerability depends critically on context, and the factors that make a system vulnerable to a hazard, will depend on the nature of the system and the type of hazard in question. Vulnerability is also described as the extent to which a system is susceptible to sustaining damage from climate change (Schneider *et al*., 2001). It can be considered as a dynamic state or condition that is influenced by both biophysical and socioeconomic conditions (Dow, 1992; Bohle *et al*., 1994; Kasperson *et al*., 2001; Liverman, 2001).

In order to understand the vulnerability and adaptive capacity of small-scale shrimp farmers to climate change, NaCSA societies are thought to be representative. NaCSA has organized 107 societies with 2568 farmers in Krishna District alone as this is being the key district having the maximum potential area as on 31 December 2009 (NaCSA, 2009b). The no. of farmers practicing shrimp culture including the societies are 3236 (Source: Department of Fisheries, Krishna district, 2008-09 Machilipatnam Unpublished). The rapid survey by Department of Fisheries during 2004-05 assessed that the actual brackishwater area developed into shrimp ponds in Krishna District was 28906 ha and the area under culture was 14767 ha. Out of the developed and cultured area, 87 and 88 % of the area was within the coastal regulation zone (CRZ) and 13 and 12% was outside the CRZ, respectively. In the present study the farmers having a farm within the CRZ are included in the coastal area and outside CRZ as inland. A total of 300 farmers were surveyed in 2010 from inland and coastal areas in four *mandals* (sub-district administrative unit) of the district viz., Machilipattinam, Bantumilli, Koduru and Nagayalanka of Krishna district Fig.9. This is approximately 10% of the total population of farmers doing the culture and the farmers for the survey were selected in each mandal following the randomization procedure. Out of the 300 farmers surveyed, 243 belonged to a society and 57 to non-society, 240 farmed in the coastal area and the remaining 60 from inland area. Further sub-grouping indicated that out of 243 society farmers, 198 were coastal and 45 from inland and out of 57 non-society farmers 42 were coastal and 15 inland (Fig.13), whereas out of 240 coastal area farmers, 198 were from society and 42 were from non-society and out of 60 inland farmers, 45 were from society and 15 from non-society. The farmers were selected based on stratified random sampling and interviewed using a pre-tested structured questionnaire that included socio-economic, farm and production details, perception of farmers to climate change events and their adaptive capacity. These farm surveys were supplemented with discussion group meetings when the information was verified further and where needed authentication obtained.

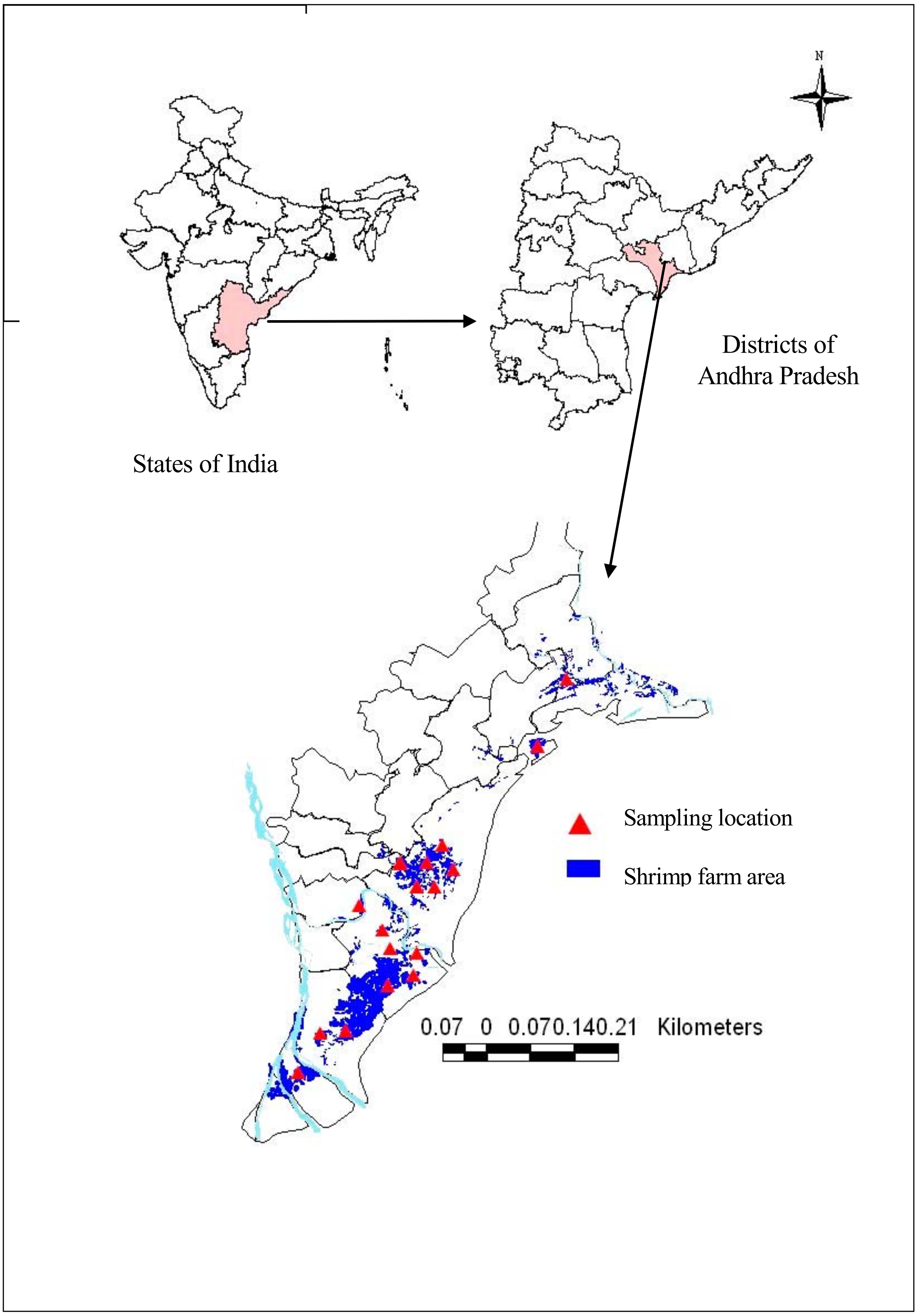


Fig. 9. Map showing coastal shrimp farming area and the sampling locations in the study area Krishna District, Andhra Pradesh

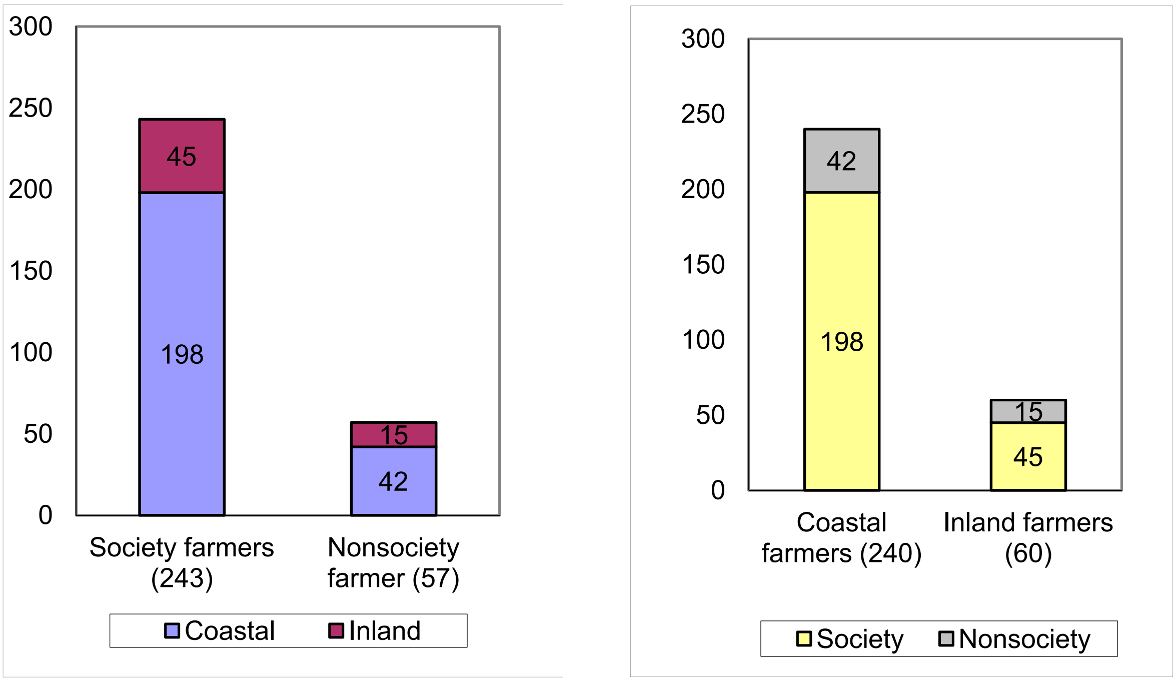


Fig.10. Distribution of surveyed farmers in different categories

4.1 Socio-economic status of shrimp farmers

In the study area all farmers cultivated tiger shrimp (*P. monodon*). The average household size for the sample was ≈ 5 (range 1-12). Also there was little difference in the average household size between the *mandals*. The average ratio of male to female members was approximately 5:4 in the households. On average, nearly half of the family members (45%) were engaged in farm activities, indicating that family labour is an important contributor to shrimp farming. Out of the 300 farmers, 264 (88%) were owners and the rest were caretakers, and farming experience averaged 14 years (range 2-20 years). Figure 10 provides the distribution of occupation and experience in aquaculture *mandal* wise.

About 41% of the farmers sampled were educated up-to primary level, 27% up to secondary level, 8% up to university level and the remainder had no formal education (Fig.11) Overall, 83% (250) of the farmers had undergone at least one training course related to aquaculture and the rest had not been through any form of training. A vast majority (82%) of the farmers has shrimp farming as the main occupation and 13% have both shrimp cultivation and fishing Table 12. Almost 81% of the farmers have membership in an aquaculture society, NaCSA. The great bulk of non-members were large scale farmers who practice intensive shrimp culture.

The analysis also revealed that on an average 46% family members were earning members showing that family labour is an important contribution to shrimp farming. Out of those who earn, 63% (or 29% of the total sample size) were males (Fig. 12). It is thus important to address both genders, while devising strategies or programs for improving their adaptive capacity.

Table.12 Distribution of farmers' occupation and years of farming experience across the study area

Mandal/ total		Main Occupation				Years of experience			Society Member	
Mandal	No.	Shrimp only	Shrimp and Fishing	Shrimp and Agicult.	Shrimp/ Fishing and Agricul.	< 5	5-10	>10	Yes	No
Machilipatnam	85	70	9	5	1	7	17	61	77	8
Bantrunulli	35	32	0	3	0	4	4	27	20	15
Koduru	80	57	23	0	0	11	23	46	66	14
Nagayalanka	100	88	8	3	1	9	26	65	80	20
Total	300	247	40	11	2	31	70	199	243	57
% of Total	100	82	13	4	1	10	23	66	81	19

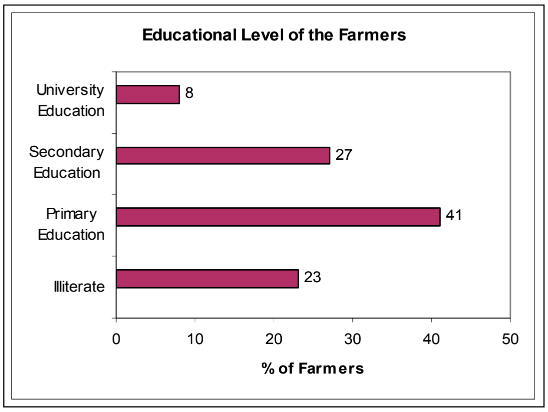


Fig.11 Percentage education level of sampled farmers

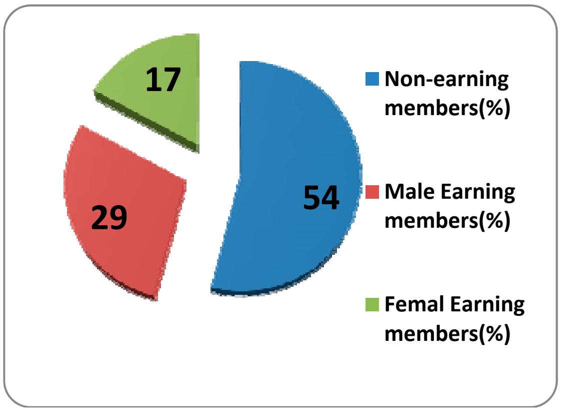


Fig.12. Percentage of earning and non-earning members among sampled farmers

4.2 Shrimp farming and production economics

Table.13 The economic analysis of shrimp farming during summer and winter crops and the annual combined costs for the two crops are presented in Table 13. The findings reveal that average cost, gross and net incomes during summer season was much higher than that in winter. The average production cost per ha during summer was IRS 80,186 (US $1 = IRS 44.00) whereas the corresponding figure for winter was IRS 12,717. It is obvious, since, summer season is the main cropping season, and hence major investments for land preparation etc, occur in this season. The average annual cost of production per ha was IRS 92,903. The annual gross income (ha^{-1}) from shrimp farming in AP was IRS 245,269 and the net income was IRS 152,366.

The breakdown of the various costs during summer, winter and the average for the year indicated that cost of feed was the major share accounting for 50% of the total costs. Fuel is the next item with a share of 23% followed by pond preparation (13%) and seed (12%) and the rest (2%) which includes cost of labour, fertilizer and electricity.

Table 13. Per hectare cost and income (in IRS; US $1 = IRS 44.00) of shrimp farming in study area (Summer crop: Feb/March to June/July; Winter crop: Aug/Sep to Nov/Dec)

Inputs	Summer crop	Winter crop	Annual average
Costs			
Pond Preparation	9729.2	2289.9	12019.0
Fertilizer	46.7	33.9	80.6
Feed	40920.9	5395.3	46316.2
Drugs	426.5	121.5	548.0
Fuel (diesel)	18123.0	3253.7	21376.7
Electricity	276.0	66.0	342.0
Labour	804.0	151.3	955.3
Seed	9859.7	1405.3	11265.0
Total production cost	80185.9	12717.0	92902.8
Income			
Gross	221901.3	23367.7	245269.0
Net	141715.4	10650.7	152366.2

4.2.1 Society and non-society farmers

The average net income of the society and non-society farmers in different mandals for the two crops is presented in the Table 14. In all the *mandals* the average income (ha^{-1}) of the non-society farmers was much higher than those of society farmers for both crops. Between the mandals, non-society members of Koduru mandal had the highest income. A non-society farmer earned a net income of IRS 170,502 as compared to a society farmer's income of 75,051. This can be explained by the fact that, most society farmers were small scale, and following extensive and semi-extensive methods of cultivation, as compared to non-society farmers who were operating larger sized farms, and practise intensive farming. NaCSA is attempting to improve the skills of society farmers, who mostly operate on a small scale. Farmers need help in terms of quality seed, feed and fuel optimization, and subsidy on inputs, especially in the periods when they are affected by extreme weather events. Shrimp farmers are not covered by any crop insurance schemes, as compared to farmers cultivating rice or other crops. It is small farmers who are more vulnerable in the event of extreme weather events and also to the long term effects of climate change. They are in a majority, and if their livelihoods have to be protected, priority should be given to improve their adaptive capacity.

Table 14. Per ha net income (IRS) (Average values with ± standard deviation) of Society and Non-Society farmers in different *mandals* in different crops (Summer crop: Feb/March to June/July; Winter crop: Aug/Sep to Nov/Dec)

Season	Category	***Mandal***				
		Machilipattnam	Bantumulli	Koduru	Nagayalanka	Combined
Summer crop	Society	44866 ± 22625.4	59149 ± 43461.5	81686 ± 50593.1	68514 ± 45167.7	65465 ± 43904
	Non-Society	136279 ± 75967.4	173640 ± 99201.3	194137 ± 141682.1	150047 ± 90025.3	159601 ± 105675.4
	Combined	125772 ± 77547	128538 ± 98887.6	174458 ± 137063.7	133740 ± 89068.4	141715 ± 103768
Winter crop	Society	4276 ± 8454	7940 ± 11090.7	1140 ± 11014.5	19224 ± 8145.4	9586 ± 11014.5
	Non-Society	14548 ± 10671.6	14112 ± 10181.3	8603 ± 17268.5	8482 ± 11333.2	10900 ± 13061.9
	Combined	13367 ± 22841.2	11680 ± 20943.5	7297 ± 20808	10631 ± 20905.1	10651 ± 21479.6
Annual	Society	49142 ± 28248.3	67089 ± 42163.8	82825 ± 50176.5	87737 ± 50687.8	75051 ± 46610.6
	Non-Society	150827 ± 80931	187752 ± 92987.3	202741 ± 143103.3	158529 ± 91668	170502 ± 107042.1
	Combined	139139 ± 83281.6	140217 ± 96878	181755 ± 139162.1	144371 ± 89489.9	152366 ± 105297

4.3 Climate change events and impacts perceived by the small-scale shrimp farmers

The climate change types perceived by the respondents in the study area along with the likelihood and consequence ratings, risk rating and the perception during the last 10 years as influenced by their association with society and location in inland or coastal areas are presented in Fig. 13. The climate change types and the associated impacts perceived are irregular season (IRS), high temperature (HTEM), cyclones (CYC), heavy rains (HR), flood (FLD) and drought (DRT), salinity increase and decrease are the major impacts that are very much relevant to the shrimp farming as a result of climate change events. The observations on type of CC and associated impacts indicated that cyclones and floods were perceived by all the farmers and IRS, HTEM, HR and DRT were perceived by 236, 267, 272 and 177 respectively.

Risk rating based on likelihood and consequence	FLD CYC & HR IRS HTEM DRT	CYC, FLD & HR IRS HTEM & DRT	CYC & FLD HR HTEM, IRS & DRT	CYC & FLD HR HTEM, IRS & DRT
Climate change event perception on priority	CYC & FLD HR HTEM IRS DRT	CYC & FLD HR HTEM IRS DRT	CYC & FLD HR HTEM IRS DRT	CYC & FLD HTEM HR IRS DRT

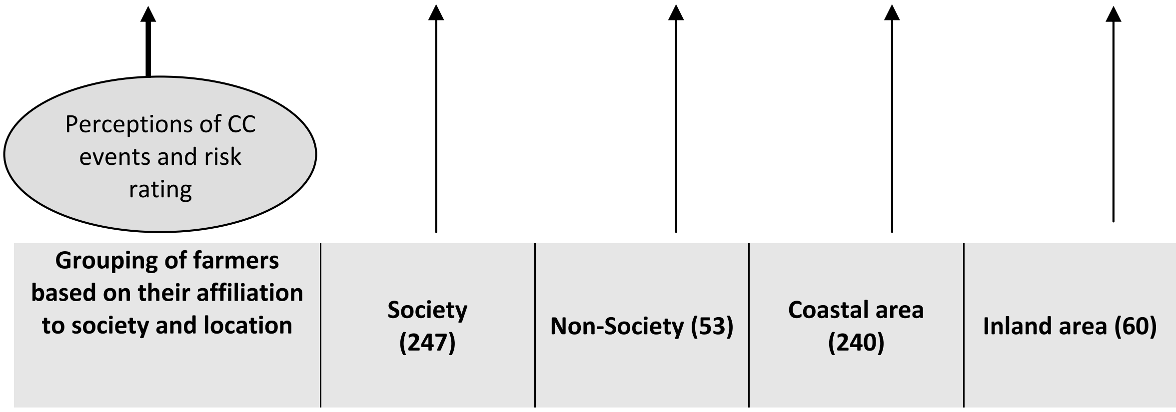


Fig.13. Perception of climate change events perceived by farmers

CC Impact Index and Gradual CC-Impact Index

Farmers provided 'YES' (score=1) or 'NO' (score=0) reply to each one of the climate change perception factors. These replies were used to construct a CC Impact Index which reflects the magnitude of their overall perception of climate change factors. This index for each CC event and impact is constructed for all the categories of farmers using the formula:

$$\text{CC Impact Index} = \frac{100 * \sum_{i=1}^{8} score_i}{8}$$

These indices always lie between 0 to 100 with 0 indicating no perception and 100 indicating maximum perception. Maximum perception was observed for CYC and FLD for all the categories of farmers followed by HR, HTEM, IRS, WSI, WSD and DRT for all the farmers in general, society and non-society farmers, whereas HTEM preceded the HR for coastal and inland farmers (Fig.14).

A similar exercise was carried out to compute Gradual CC Impact index based on the replies by the farmers to the eight factors stated above. The index had average score of 81.7 and standard deviation of 13.1.

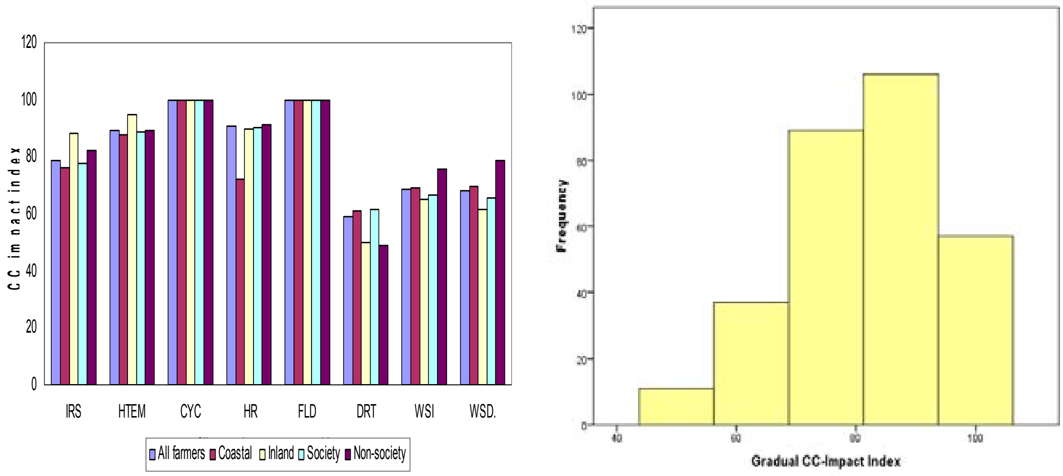


Fig.14. CC impact index and gradual CC impact index perceived by the farmers

4.3.1 Likelihood or frequency rating

The farmers were requested to rate the likelihood of occurrence of CC type and impact as almost certain, likely, possible, unlikely and rare. There was a significant difference among the CC events and impacts with respect to their likelihood occurrence. DRT, WSI and WSD come under one group with low average score of around 2.5. FLD and HTEM were highest likelihood events with average scores of 4.5 and 4.6, respectively. A similar trend was observed with society, non society, coastal and inland farmers. Coastal farmers have rated cyclone also as the most likelihood occurrence along with HTEM and FLD. Society and non-society farmers have rated HTEM as the most likelihood CC event.

Consequences of climate change

Based on the increase or decrease in economic performance and profit or failure of the business due to a particular CC type and its impacts, the consequence ratings for shrimp aquaculture are extremely positive, major, moderate positive, minor positive, insignificant positive, no consequence, insignificant negative, minor negative, moderate negative, major negative. There was a significant difference in the consequence rating between the CC events. DRT, WSI, WSD, IRS and HTEM were of less consequence to shrimp farming compared to CYC, FLD and HR. HTEM also had positive consequence as reported by some farmers in increasing thee production. In coastal and inland areas also a similar trend was observed, but CYC and FLD resulted in more damage than HR. Society and non society farmers also reported the same type of consequence of CC.

4.3.2 Production loss/gain

The production gain/loss indicated that DRT,WSI, WSD and HTEM had more or less equal loss to shrimp production ranging from 10-30 Kg/ha and the intensity of damage increased with IRS (30-42 Kg/ha), HR (90-160Kg/ha), CYC (100-400Kg/ha) and FLD (200-400 Kg/ha). The average production loss due to CC was more in coastal areas compared to inland. The average loss due to CYC and FLD was 316.5 and 311 Kg/ha in coastal area compared to 115.8 and 251.7 Kg/ha in inland area. However, this type of comparison was not observed between society and non-society farmers (Table 15).

4.3.3 Economic loss/gain

CYC and FLD caused more economic loss compared to other events. Highest loss of Rs.102,000 was reported with FLD. Since the farmers in these areas were recently effected by floods in Krishna river, they were able to provide exact estimates for the floods. Like production loss in quantity, economic loss was also high with farmers in coastal area compared to inland (Table 2 and 3). Average economic loss was Rs. 106,000 and 108,000 with FLD and CYC in coastal area compared to Rs. 86,000 and 39,600 in inland areas. In inland areas higher loss was reported due to FLD and HR. There was not much difference between society and non-society farmers in terms of economic loss to shrimp farming. (Table 15)

4.3.4 Risk rating

Farmers' perceptions of the risks associated with climate change viz., risk rating and economic risk rating were calculated from the values of likelihood and consequence rating and economic loss indicated that the highest RR CC factor was FLD and the least RR factors were DRT, WSI and WSD with all the categories of farmers. Economic risk was calculated by multiplying the likelihood of an event with the economic loss. The highest economic risk rating (ERR) was with FLD (463,000) followed by CYC (394,000). Though a similar trend was observed in coastal and inland areas and society and non-society farmers, the ERR was higher in coastal areas compared to inland and there was no significant difference between society and non-society farmers. (Table16)

Overall, climate change impact was significantly less with respect to inland farmers compared to other categories which do not differ significantly (Table15 & 16).

Table.15. Production and economic loss by farmers from different groups due to climate change events

Climate change type	Observation (Y/N)	Production loss (kg)		Economic loss (Rs)	
		Coastal	Inland	Coastal	Inland
Irregular season	236/64	20-42 ($30.8^{c} \pm 5.7$)	21-42 ($30.47^{b} \pm 5.5$)	6800-14910 ($10500^{d} \pm 1988$)	6930-14490 ($10400^{b} \pm 1873$)
High temperature	267/33	10-20 ($16.13^{a} \pm 3.8$)	10-20 ($14.79^{a} \pm 4.2$)	3300-7100 ($5506.44^{a} \pm 1323$)	3300-7100 ($5064.8^{a} \pm 1455$)
Cyclone	300/0	300-400 ($316.5^{f} \pm 34.8$)	100-160 ($115.8^{c} \pm 20.3$)	99000-142000 ($108000^{g} \pm 12104$)	33000-54400 ($39600^{c} \pm 7058$)
Heavy rain	272/28	90-160 ($116.5^{d} \pm 19.5$)	100-160 ($125.7^{d} \pm 14.2$)	31950-56800 ($39800^{e} \pm 6798$)	35500-56000 ($42900^{d} \pm 5035$)
Flood	300/0	220-400 ($311^{e} \pm 44$)	200-400 ($251.66^{e} \pm 52.1$)	72600-142000 ($106000^{f} \pm 15262$)	66000-102000 ($86000^{e} \pm 18100$)
Drought	177/123	10-30 ($21.8^{b} \pm 5.2$)	10-30 ($20.16^{a} \pm 3.8$)	3000-10650 ($7252.38^{a\,b\,c} \pm 1790$)	3000-9000 ($6270^{a} \pm 1197$)

Table.16 Average likelihood and consequence rating and risks perceived by different groups of shrimp farmers

Farmer's category	Likelihood and consequence ratings				Risk	
	Likelihood/ frequency	Consequence				
	Rating (1-5)	Rating (-5 to +5)	Production loss (kg)	Economic loss (Rs)	Risk rating	Economic risk rating
Society	3.83 [b]	-3.37 [a]	117.91 [b]	40200 [b]	-13.23 [a]	172000 [b]
Non society	3.78 [a]	-3.17 [b]	113.24 [b]	38600 [b]	-12.33 [b]	161000 [b]
Coastal	3.85 [b]	-3.43 [a]	124.34 [b]	42400 [b]	-13.60 [a]	182000 [b]
Inland	3.67 [a]	-2.92 [c]	86.9 [a]	29700 [a]	-10.86 [b]	117000 [a]

4.4 Climate changes that have become stronger and difficult to overcome

All the categories of farmers ranked in similar way to overcome the CC type with serious losses. Garrett ranking scores revealed that FLD (21630) followed by CYC (18870), HR (13550), HTEM (12580) and IRS (8370) are the most difficult CC events in the decreasing order (Fig.15 A). The CC event that has become stronger and more frequent was CYC (21900), HTEM (17100), FLD (13200) and HR (8400) and the similar rating was observed with society and non-society farmers (Fig.15 B).

A **B**

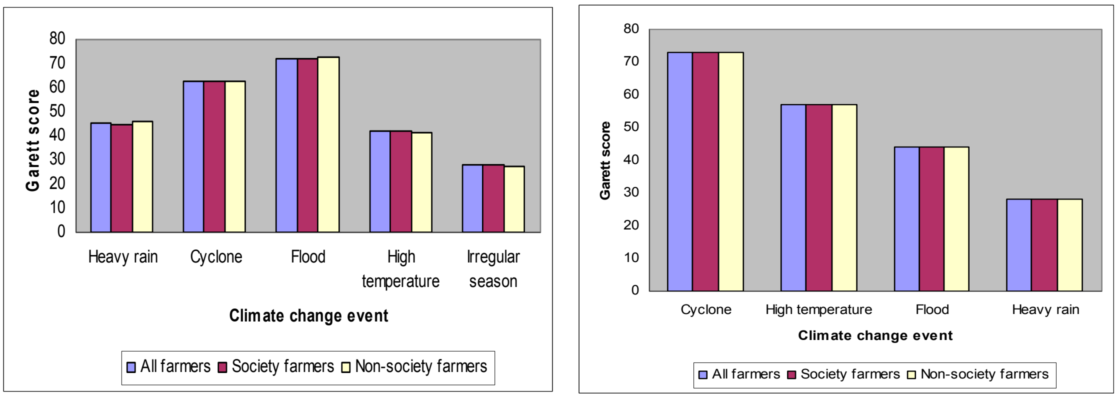
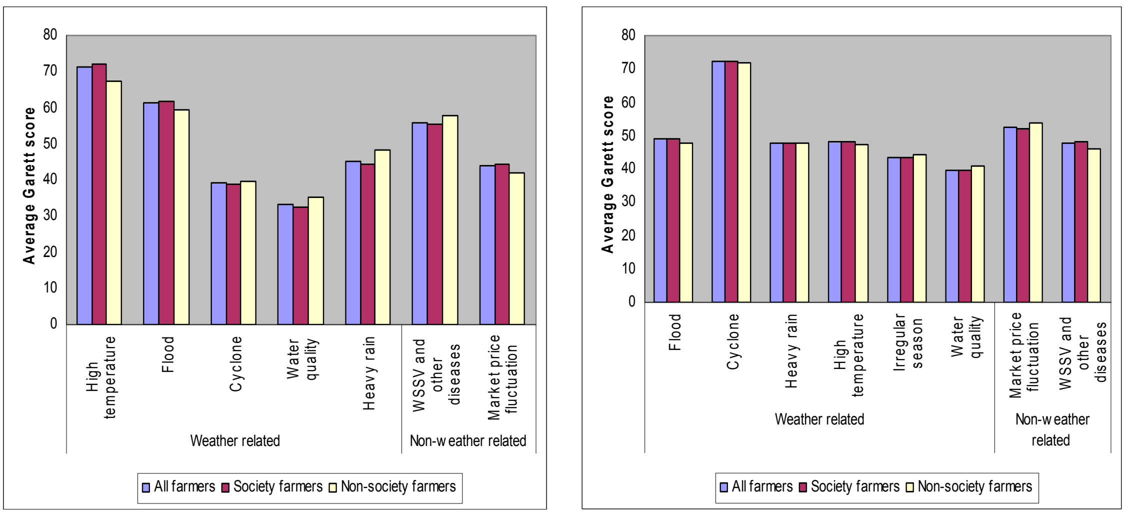


Fig.15. Climate change events that has become difficult to overcome (A) and that have become stronger and more frequent

4.5 Weather and non-weather related problems in the present and future

Comparison of weather and non-weather related problems in the present and future through Garrett scores revealed that CYC, FLD, HTEM, HR, IRS and water quality are the most weather related problems in the order at present. Society farmers have ranked in the same way, whereas non-society farmers have ranked CYC, HR, FLD, HTEM, IRS and water quality as the weather problems in the recent past. All the categories of farmers ranked market price fluctuation as the first non-weather related problem followed by WSSV and other diseases (Fig. 16).

In future, HTEM, FLD, HR, CYC and water quality are the major weather related problems for non-society farmers, whereas HTEM, FLD, HR, water quality and CYC are the major problems for society farmers (Fig.16). Disease problems was the most non-weather related problem for all the farmers in the future compared to the fluctuations in market prices as many believe that CC will induce new diseases into the aquaculture systems (Fig.16).



A. Present **B. Future**

Fig.16. Weather and non-weather related problems in the present and future

4.6 Technical efficiency of shrimp farmers

In addition to descriptive statistics, *a Stochastic Frontier Function* and *Cobb Douglas function* were used to study the technical and economic efficiencies of the farmers, respectively. The present study attempts to explain the difference in efficiencies using socio-economic and climatic variables. Inclusion of climatic variables is a novel approach in this analysis. The technical efficiencies were computed by fitting 'Stochastic frontier function' to the data on inputs and the output. A brief discussion of this methodology is given below:

Let us assume that each farm uses *m* inputs (vector *x*) and produces a single output *y*. Following Aigner *et al*. (1977) and Meeusen and van den Broek (1977), it can be assumed that the production technology of the i[th] farm is specified by the stochastic frontier production function

$$y_i = f\left(x_i;\beta\right)\exp\left(\varepsilon_i\right) \quad (1)$$

where *i*=1,2,….*n* refers to farms, β is a vector of parameters and ε_i is an error term and the function $f\left(x;\beta\right)$ is called the 'deterministic kernel'. The frontier is also called as 'composed error' model because the error term ε_i is assumed to be the difference of two independent elements,

$$\varepsilon_i = v_i - u_i \quad (2)$$

where v_i is a two sided error term representing statistical noise such as weather, strikes, luck etc which are beyond the control of the farm and $u_i \geq 0$ is the difference between maximum possible stochastic output (frontier) $f\left(x_i;\beta\right)\exp\left(v_i\right)$ and actual output y_i. Thus u_i represents output oriented technical inefficiency. Thus the error term ε_i has an asymmetric distribution. From (1) and (2), the farm-specific output-oriented technical efficiency is given by

$$TE_i^o = \exp\left(-u_i\right) = y_i \big/ \left\{ f\left(x_i;\beta\right)\exp\left(v_i\right)\right\} \quad (3)$$

Since $u_i \geq 0$, $0 \leq \exp\left(-u_i\right) \leq 1$ and hence $0 \leq TE_i^o \leq 1$. When u_i = 0 the farm's output lies on the frontier and it is 100% efficient. Thus the output oriented technical efficiency tells how much maximum output is possible with the existing usage levels of inputs. The estimation of stochastic production frontier function may be viewed as a variance decomposition model. The variance decomposition can be expressed as:

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \quad (4)$$

and

$$\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2} \quad (5)$$

In the literature the common functional forms used to represent the deterministic kernel are 'Cobb-Douglas' and 'Translog'. The 'Cobb-Douglas' function in log form can be stated as

$$\ln\left(y_i\right) = X_i\beta + v_i - u_i \, , i = 1,2,...n \quad (4)$$

where X_i is a vector consisting of the logarithms of m inputs. Maximum Likelihood Estimation procedure is followed to estimate the frontier production function. In the present study the Cobb-Douglas function was used with the following variables:

Dependent Variable: Y = yield of shrimp in kg
Independent Variables: Feed quantity (kg), Hired labour (days), Seed quantity (in '000s), Pond preparation cost and Fuel and other costs (all in Indian Rupees).

The estimated parameters of the production functions are given in Table 17. It shows that feed has a significant contribution to yield. Feed also occupies a major part of the input costs. It was also observed during the field visits that there is a lack of adequate knowledge on the optimim feeding schedules. Excess feeding also results in wastage, increased costs to farmers and pollution of water bodies. All the other inputs were found to be non-significant. The value of γ, the ratio of variance due to inefficiency to the total variance was significant ($P< 0.05$).

Table 17. Maximum-likelihood estimates of the stochastic Cobb-Douglas production frontier function

Variable	Coefficient	t-value
Intercept	1.6552	1.70
Log (Feed)	0.7296	2.0384**
Log (Hired labour)	0.0025	0.0030
Log (Seed)	0.3179	0.4519
Log (Pond preparation cCosts)	-0.2049	-0.2328
Log (Fuel and other costs)	0.0728	0.0861
γ	0.9913	1.931**
σ^2	0.0382	0.6612
Log-likelihood	226.3	

Source: Farmers surveys conducted in 2009-2010 in Krishna district of Andhra Pradesh
** Significant at 5% level

The fitted frontier model was then used in equation (3) to estimate the efficiencies of the individual farmers. The mean technical efficiency was estimated to be 87% implying that on the average farmer is producing 87% of the maximum possible output. It is evident from Table 18 (frequency distribution of the efficiencies) that about 54% of the farmers are more than 90% efficient. The high efficiency may be attributed to the use of better quality feed, seed stock and adoption of latest technology in farming. However, a majority of these constitute large farmers who were carrying out intensive and semi-intensive method of cultivation. Whereas, small scale farmers mostly practise extensive method of cultivation.

Table.18. Frequency Distribution of the efficiencies of the farmers

Range	Frequency	Farms (%)
> 90	163	54.3
80-90	80	26.7
70-90	1	0.3
60-70	50	16.7
< 60	6	2.0

As already stated, technical efficiency measures the efficiency in utlization of resources. A 100% technically efficient farm will lie on the frontier and it produces maximum possible output using all the resources in an optimal way. Many authors (Timmer, 1971; Muller, 1974; Kalirajan and Shand, 1989) have suggested that the discrepancies in efficiencies can be explained by regressing technical efficiency with the socio-economic and demographic factors of the individual farmers. But in the present study, since some farmers were using different adaptation strategies to overcome the negative effects of climate change, it was considered more pertinent to include the effect of the various strategies also along with socio-economic factors. This will help to determine whether the strategies of the farmers to climate change really help in improving their efficiencies. Accordingly, the variables used in the regression equation thus developed are given in Table 19.

Table 19. Dependent and Independent variables impacting the technical Efficiency of individual farmers

Socio-economic variables	**Climatic variables**
Stocking density	Cyclone Storm –Level of Success (CYCLS)
Farming experience in years (FEXPYR)	Flood from rain – Level of Success (FLDLS)
Water spread area	Irregular Season Observation (IRSOBSV)
Education level (REPEDU)	Observation of Low temperature change (LTEMOBS)
Trainings undergone or not (TRNATTND)	Drought Observation (DRTOBS)
Member of Society or not (Society=1; Non-society=2) (SOCNSOC)	Water salinity increase observation (WSIOBS)

The climatic variables were selected from a list to which farmers responded in the survey. The estimated parameters of the regression model are presented in Table 20. The high R^2 values indicate the adequacy of the model. Among socio-economic variables, stocking density, farming experience and society membership has significant influence on the efficiencies. The coefficient of the SOCNSOC is significant and positive indicating that non-society members were more efficient than society members. This was also supported from the values of net income of non-society members which was much higher than those of society members. This is also justified by the fact that most non society members were large sale farmers. All other socio-economic variables were not significant although their coefficients have a positive sign.

Among the climatic variables, cyclone storm – level of success and flood from rain – level of success, were the only two variables which were significant. Further the coefficients of these variable were positive indicating that those farmers who had successfully overcome the negative effect of cyclone storm and floods have increased their efficiency levels. All other climate variables were found to be non-significant.

Table 20. Efficiency differentials across shrimp farmers in the study area. Note that abbreviations for independent variables in Table.19 are used here also.

	Coefficients	***Standard Error***	***t Stat***
Intercept	0.33707	0.01967	17.140
Water spread area	-0.00250	0.00316	-0.791
Stocking density	0.00215	0.00110	1.958*
FEXPYR	0.00073	0.00041	1.771*
REPEDU	0.00050	0.00260	0.193
TRNATTND	0.00269	0.01534	0.175
SOCNSOC	0.27589	0.01467	18.805***
CYCLS	0.01641	0.00484	3.393***
FLDLS	0.01238	0.00475	2.607***
IRSOBSV	0.00575	0.00550	1.046
LTEMOBS	0.00073	0.00496	0.146
DRTOBS	-0.00180	0.00460	-0.391
WSIOBS	-0.00496	0.00495	-1.001
R^2	0.895		
F-statistic	203.9		

*Significant at 10% level; *** Significant at 1% level

5. Green House Gas production and resource use bench marking

5.1 Introduction

In order to identify culture systems that produce the most Green House Gases (GHGs) and prioritise better practices for the culture systems with high environmental impact, the different case studies need to be benchmarked against each other and other aquaculture technologies. This analysis uses resource use analysis to estimate the resource use and nutrient impact to the environment and Life Cycle analyses to estimate GHG emission. In this way the aquaculture culture systems that are resource heavy or have high GHG emissions can be highlighted and best practice guidelines to reduce impacts. The analysis assesses the GHG emissions and resource use per tonne of food produced by the shrimp culture systems.

The Bangkok Declaration expressed the need to develop resource-efficient farming systems which make efficient use of water, land, seed and feed inputs by exploring the potential for commercial use of species feeding low in the food chain. Although significant resource competition exists, significant technological advancements in aquaculture over the past decade have occurred to make production systems less consumptive of land, water and energy, to the point where aquaculture resource use, overall, is comparable to poultry production.

However, the next 20 years will see an increase in the efficient use of land, water, food, seed and energy through intensification and widespread adoption of integrated agriculture-aquaculture farming ecosystems approaches. However, this will not be enough to increase aquaculture production as these will improve only the efficiency of use, and increase aquaculture yields per unit of inputs. An exponentially growing population will require aquaculture to expand rapidly into land and water areas that are currently held as common pool resources (commons). This raises issues of access to and management of common pool resources, which could result in conflicts with exiting users and potentially acute social, political, and economic problems.

Assessing environmental performance of aquaculture is difficult because activities and potential impacts are extremely diverse. However there is an increasing emphasis on using holistic analyses to compare overall impacts of different agricultural production systems and to assess impacts and resource use within a production process to identify opportunities for increasing resource use efficiency. Life Cycle Assessment is the most common comprehensive analytical tool currently used to quantify environmental impacts of a production process. The LCA concept has been formalized into an analytical methodology under ISO 14000 standards and has been proposed as a measure of environmental performance and sustainability by numerous agencies and environmental groups

The LCA approach is useful because the impacts of all activities involved in production, use, and retirement of a product are expressed in a single “common currency” for example energy use, thereby making it easy to compare impacts among various products, processes, or activities. Life cycle assessment must have clearly defined boundaries because impacts can, in theory, flow almost endlessly upstream and downstream of the actual production process. For example, an energy LCA for aquaculture may include energy costs to procure pelagic fish for reduction to fish meal that will be used in aqua feeds. The energy cost of fishing is primarily embodied in the fuel used by the fishing vessel, but can also include the energy used to manufacture the fishing vessel, to produce the steel and fiberglass used to fabricate the vessel, to produce the nylon used in nets, and so on. In this analysis the boundary for analysis is set to the production phase only. Production data and resource use was collected through detailed questionnaires from owner operators. Combining the power of LCA with individual resource use indicators based on specific impacts provides a comprehensive set of tools for assessing environmental performance.

5.1.1 Feed use

Nutrient requirement for the shrimp production in ponds is provided either by natural productivity of the pond or by feed. This ratio varies with the culture system. A large proportion of the nutrient requirements for semi-intensive shrimp pond production are provided by pond water productivity (phytoplankton, zooplankton and other micro organisms) which is enhanced by using organic and/or inorganic fertilisers.. In some cases aquaculture feed often incorporates high levels of fish meal and fish oil provided from wild stocks and so aquaculture fish may not be a net producer of fish. Aqua feeds usually are the most costly aquacultural input, and feed ingredient production, feed manufacture and feed transport constitute large proportion of energy inputs to aquaculture production. The efficiency of feed use varies between species, feed quality and feeding strategy.

Not all the nutrients profiled through the feed are taken up by the fish with the majority of nutrients lost to the environment either as solids (uneaten feed or faeces) or as dissolved nutrients (excretion). These nutrients are assimilated by the environment but if there are excess nutrients, they can form an anoxic layer on the seabed surface or cause eutrophication or trigger algal blooms. It is also significant to note that the amount of waste generated per unit of production decreases as the FCR declines.

The most widely used indicator of production and feed use efficiency in aquaculture is the feed conversion ratio (FCR). This indicator is calculated as follows:

$$FCR = \frac{\text{feed provided, kg}}{\text{Net aquacultural production, kg}}$$

Aquaculture uses most of the world's fishmeal (68%) and fish oil (88%) with the balance used by intensive livestock agriculture and for pet foods (Tacon, 2005; Tacon et al., 2006; Tacon and Metian, 2008). Salmon, trout and shrimp aquaculture which account for less than 10% of world aquaculture production, use an estimated 26% of the world's fish meal, but 74% of the fish oil (Tacon and Metian, 2008). However, Tacon and Metian (2008) predict that fishmeal and oil use in aquaculture will decrease while aquaculture production grows significantly, and that fish meal/oil will increasingly be diverted from uses as bulk feed products to high priced, specialty, feed ingredients.

5.1.2 Fish Oil

Fish oil also is a component of some of aquaculture feeds. There is a finite supply of fish meal and oil. Because fish oil has traditionally been viewed as a by-product of fish meal production, more concern has been expressed in the past about the fish meal supply than the fish oil supply. The yield of fish oil from reduction fisheries is significantly lower than the yield of fish meal. This suggests that fish oil may in the future be a scarce commodity than fish meal for use in aqua feeds. It takes 10 to 20 kg live fish to produce a kilogram of fish oil, but the quantity varies greatly by species and season (Tacon et al., 2006).

However, "fish-oil ratios" and feed-fish equivalences that include oil are more difficult to calculate and interpret than those for fish meal because of the large variation in fish oil yield and the history of fish oil as a by-product of fish meal production. Nevertheless, the wild fisheries conservation benefit of substituting vegetable oil for fish oil in aquafeeds is great. The main problem with complete substitution is that marine species need long-chain polyunsaturated fatty acids in their diet and fish oils are an excellent source. Also, the fatty acid profile of fish produced on feeds containing only vegetable oil is different than fish produced with feeds containing fish oil, and this may change the taste of the fish.

5.1.3 Fish meal

Fish used for making fish meal are provided primarily from wild pelagic fishery. In fish meal manufacturing, the ratio of live fish to fish meal is about 4.5. Fish meal can also be produced from the offal from processing of wild-caught or aquacultured fish. Offal contains more ash and less protein than live fish, and fish meal from offal is of lower quality than that from live fish. Nevertheless, fish meal from offal can be used in many applications to supplement marine fish meal. Shrimp heads from processing can be used to make shrimp head meal that can be used in animal feeds.

Environmentalists are concerned over inefficient use of feed fish to make fish meal and fish oil for aqua feeds. Feed fish are a component of world fisheries production, and it can be logically argued that unless a Fish-in to fish out ratio (FIFO) of 1.0 or less is obtained, feed-based aquaculture detracts from world fisheries production.

Currently, about 40% of aquaculture depends on formulated feeds: 100% of salmon, 83% of shrimp, 38% of carp (Tacon and Metian, 2008). An estimated 72% of all use of global aquafeeds is by low trophic level herbivorous and omnivorous aquatic organisms (carps, tilapias, milkfish and shrimp) each of which dominates in various countries.

5.2 Fish-in Fish-out Ratio (FIFO)

One of the current concerns in the aquaculture sector is the amount of wild fish that is required to produce farmed fish. A number of different methods have been developed to calculate the amount of wild fish that it takes to produce one tonne of farmed fish. One such methodology is based on the Fish-in : Fish-out ratio (FIFO ratio). Using dry pellets, FIFO ratios for salmon ranged between 3:1 to 10:1 with Tacon and Metian (2008) calculating a FIFO ratio of 4.9:1 for salmon production, indicating that 4.9 tonnes of wild fish are required to produce 1 tonne of farmed salmon (Table 21).

A number of authors have developed methodologies for calculating FIFO ratios. These include:

- Tilapia Aquaculture Dialogue draft v2.0 (WWF, 2009)
- Tacon and Metian (2008)
- International Fishmeal and Fish Oil Organisation (IFFO) methodology (Jackson, 2009)
- EWOS methodology for fatty fish such as salmon (EWOS, 2009)

Table 21. Trends in Fish-In Fish-Out Ratios from 1995 to 2008 (Tacon and Metian, 2008).

Subsidised aquaculture	**FIFO (1995)**	**FIFO (2008)**
Salmon	7.5	4.9
Trout	6.0	3.4
Eels	5.2	3.5
Misc. Marine Fish	3.0	2.2
Shrimp	1.9	1.4
Net production aquaculture		
Chinese and Indian major carps		0.2
Milkfish		0.2
Tilapia		0.4
American catfish		0.5
Freshwater prawns		0.6

The following provides a brief review of the assumptions that are used in the various models.

5.2.1 Tilapia Aquaculture Dialogue draft v2.0 Methodology

These models are based on the weight of fish caught and produced, and provide Fish Feed Efficiency Ratios for fishmeal and fish oil.

$$\text{FFER meal} = \frac{(\%\text{ fish meal in feed}) \times (\text{eFCR})}{22.2}$$

$$\text{FFER oil} = \frac{(\%\text{ fish oil in feed}) \times (\text{eFCR})}{5.0}$$

The model assumes that the fishmeal produced from the fish caught for fish oil is wasted.

5.2.2 Tacon and Metian (2009)

The method used by Tacon and Metian (2009) effectively assumes that the excess fishmeal produced from the fish caught for fish oil is wasted. In fact it is used as ingredients and materials for other feed production. The IFFO (2009) method addresses this issue, but fails to recognise that cultured salmon have a higher lipid level than the average wild fish. The models assume a yield of fishmeal and fish oil of 22.5 and 5 percent on a wet weight to dry weight basis respectively.

5.2.3 IFFO methodology (Jackson, 2009)

The IFFO method applies the following equation:

$$\text{IFFO FIFO Ratio} = \frac{\text{Level of fishmeal in the diet + level of fish oil in the diet}}{\text{Yield of fishmeal from wild fish + level of fish oil from wild fish}} \times \text{FCR}$$

This model corrects the Tacon and Metian (2009) model that implies that the extra fishmeal is wasted and takes into account of both the fishmeal and fish oil use. However, the model is biased against fish with high lipid levels such as salmon, trout and eels due to the differential between some species of cultured fish with high lipid level compared to wild fish used for the production of fish meal and fish oil.

5.2.4 EWOS methodology

The EWOS model compensates for fish that have relatively high fish oil concentrations (e.g. salmon) on the basis of nutrients used and produced, and compares the ratios using the same assumptions (fish meal and fish oil yields). The nutrient based ratio corrects this bias, and is the preferred ratios to use for fatty fish such as salmon, trout and eels. The calculations are as follows;

For Marine Protein:

$$\text{Marine Protein Dependency Ratio} = \frac{\text{kg marine protein used}}{\text{kg marine protein produced}}$$

$$\text{MPDR} = \frac{\text{FMfeed} \times \text{PrFM} \times \text{eFCR}}{\text{PrtSalm}}$$

Where,

MPDR Marine Protein Dependency Ratio

FMfeed Concentration of fishmeal in the feed (%)

PrFM Concentration of protein in fishmeal (as a proportion)

eFCR economic Feed Conversion Ratio
PrtSalm Concentration of protein in the salmon on whole fish basis (%)

For Marine Oil:

$$\text{Marine Oil Dependency Ratio} = \frac{\text{Kg marine oil used}}{\text{Kg marine oil produced}}$$

$$\text{MPDR} = \frac{(\text{Fofeed x FMfeed x FoFM})) \text{ x eFCR}}{\text{OilSalm}}$$

Where,
MODR Marine Oil Dependency Ratio
FoFeed Concentration of fish oil in the feed (%)
FMfeed Concentration of fishmeal in the feed (%)
FoFM Concentration of fish oil in fishmeal (as a proportion)
eFCR economic Feed Conversion Ratio
OilSalm Concentration of oil in the salmon on whole fish basis (%)

For the purpose of this report, the IFFO formula was adopted and used to analyse the results of this study as the trial species do not have high lipid levels when compared to salmon, and accounts for other uses of the unused fishmeal and fish oil which is not the case with the method used by Tacon and Metian (2009).

The estimated FIFO ratios for for the case study culture systems used the following formula;

$$\frac{\text{Level of fishmeal in the diet + level of fish oil in the diet}}{\text{Yield of fish meal from wild fish+ yield of fish oil from wild fish}} \quad \text{x} \quad \text{FCR}$$

The results indicate that the FIFO ratio for the shrimp case study culture systems was 1.23 and benchmarked against other estimated FIFO ratios in Table 22.

Table 22. Fish In Fish Out Ratios (Adapted from Tacon and Metian, 2008)

Subsidized aquaculture	**FIFO (2008)**
Salmon	4.9
Trout	3.4
Eels	3.5
Misc. Marine Fish	2.2
Shrimp	1.4
Shrimp in India (Aquaclimate)	1.23
Net production aquaculture	
Freshwater prawns	0.6
American catfish	0.5
Tilapia	0.4
Chinese and Indian major carps	0.2
Milkfish	0.2

5.3 Water Use

Water use in aquaculture can be extreme—as high as 45 m3/kg of fish production (FAO). The potential for increased water use efficiencies in aquaculture is higher than terrestrial systems. Globally about 1.2 m3 (or 1200 liters) of water is needed to produce 1 kg of grain used in animal feed (Verdegem et al., 2006). A kg of tilapia can be produced with no consumptive freshwater use (cages, seawater farming systems), or using as little as 50 L of freshwater (Rothbard and Peretz, 2002). Seawater aquaculture systems (mariculture) can use brackishwaters unsuitable for agriculture; plus, integrated, land-based saltwater faming is possible (Fedoroff et al., 2010).

Water use in aquaculture may be classified as either total use or consumptive use (Boyd, 2005). Total water use is the sum of all inflows (precipitation, runoff, seepage, and management additions) to production facilities. Much of the water entering production facilities passes downstream in effluent discharge. Consumptive water use includes reduction in stream flow as a result of increased evaporation and seepage from the aquaculture facility, freshwater from wells, and water removed in biomass of aquatic animals at harvest (Boyd, 2005). Water in harvest biomass averaged about 0.75 m^3/t a minor quantity that can be ignored usually.

Boyd (2005) proposed indices for water use and water value that can be calculated for either total or consumptive use as follows:

$$\text{Water use index, m3/t} = \frac{\text{Water use, m3}}{\text{Production, t}}$$

Total water use varies greatly in aquaculture depending mainly upon the culture method used. Cage and net pen culture use water passively as it passes through the nets by the currents and raceway culture uses the most water where water actively passes through the tanks by gravity or pump. Water use in ponds varies with the intensity of production, frequency of draining, and amount of water exchange employed.

Consumptive use of freshwater in aquaculture is an important conservation issue. Total and consumptive water use is the same for cage and net pen culture, for the only water consumed is that incorporated into biomass. In raceway culture, water in biomass plus evaporation from raceways is consumptive use. The water use index for Indian shrimp case study was 12,633 m^3/ton and was benchmarked against high water use systems(>10,000 cubic meter per tonne product) in Table 23.

Table 23. High water use (average use >10,000 cubic meters/tonne product)

Systems	**Estimated water Use (m^3/t product)**	**Comments**
Shrimp farming in ponds	11,000 – 43,000	Beveridge et al. (1991)
Fish culture	11,500	Fed freshwater species Verdegem et al. (2006)
Trout (90% recycling)	25,000 (252,000 withdrawal)	Brummett (1997)
Fish in freshwater ponds	30,100	Production of 30 MT/ha/yr with20% water exchange, Verdegem et al. (2006)
Shrimp culture in India	12,633	AquaClimate
Extensive fish culture	45,000	No feed Verdegem et al. (2006)
Pangasius catfish Vietnam	up to 59,700	Wide range from 700 to 59,700 Phan et al. (2009)
Trout (75% recycling)	63,000 (252,000 withdrawal)	Brummett (1997)

Total water use is important where water is pumped into aquaculture facilities, for there is an energy cost for doing so. In marine shrimp culture, large amounts of water may be pumped into ponds to effect water exchanges. Total water use also is important where water right issues are involved.

Competition may occur between aquaculture and other water uses (Yoo and Boyd, 1994; Boyd et al., 2005). Withdrawal of groundwater for use in ponds may lower water table levels and lessen the discharge of other wells in the vicinity. Installation of several ponds on a watershed may lessen downstream flow. Some large, flow-through aquaculture facilities may take water from streams, irrigation systems, or other sources and discharge into different water courses. Although these aquaculture facilities do not consume large amounts of water, they may alter downstream flow patterns and lessen the amount of water available to other users. Cage and net pen culture consumes little water and coastal ponds for brackish water aquaculture consume none. Nevertheless, these facilities may interfere with the use of water bodies or adjacent land areas by other resource users.

5.4 Land use

Aquaculture uses land in two ways. First, aquaculture facilities occupy a defined area or space on land or in water; however, facility area accounts for only a portion of the total land or water area needed to produce an aquaculture crop. Additional ecosystem area is needed to provide support or service functions. The two most important of those functions are food production and waste treatment (Boyd, 2006; Boyd and Polioudakis, 2006).

Land-based aquaculture converts land surface area to water surface area. Pond production data reflect this land use when reported as biomass harvested per unit water surface area. However, land use for production facilities in not always conveniently reported in real terms. Production in raceways, tanks, and indoor water reuse systems is reported on a volume (kg/m3, for example) or water-flow (kg/m3 per sec, for example) basis because the culture unit surface area usually is small. Cages, net pens, and shellfish plots do not use land in the traditional sense, but they occupy space in water bodies.

When expressed on an area basis, the land or water area needed per unit production of aquaculture crop varies over more than two orders of magnitude. At one extreme are highly intensive water recirculating systems, which are capable of annually producing 1,000 to 2,000 tonnes of fish per hectare of culture unit (Timmons et al., 2001) or 350 tonnes of Pangasius catfish per hectare. Fish and shrimp production in ponds requires several hundred times the land area compared with intensive recirculating systems.

In addition to surface area devoted to culture of aquatic organisms, land surface area must be dedicated to support of production facilities. Pond aquaculture requires embankments, intake and discharge canals, settling basins, and pump stations. Aquaculture facilities have access roads, parking lots, storage areas, staging areas, space for administrative and service buildings, etc. Boyd (2010) estimated that with watershed catfish ponds in Alabama that the land used for support purposes typically is about 25% of pond water surface area. Watersheds normally have other uses, and although necessary for aquaculture, they are not dedicated specifically to aquaculture.

In marine shrimp culture, canals are used to supply and discharge water at farms. Farms of 25 ha or more in size usually have support areas of about 25% of water surface areas, but the support area may increase to as much as 50% at smaller farms. Catfish pond facilities in Mississippi typically have only 10–15% of the total land area devoted to support, and the support area as a proportion of total land area decreases slightly as farm size increases (Keenum and Waldrop, 1988). For a farm with a total land area of 65 ha, 2% of the area is used for buildings, parking, feed storage, etc., 13% of the area is in embankments, and the water surface comprises 85% of the area. For a farm with a total area of 260 ha, the estimates are 1%, 11%, and 88%, respectively.

The Land use for shrimp case study culture system in India was 14,095 m^2/ton and was benchmarked against other estimates of land resource use in Table 24.

Table 24. Efficiencies of land use for aquaculture system. Adapted from Verdegem et al. (2006).

System types	Descriptions	Production (kg/ha/year)	Efficiency of land use (m2/MT)
Extensive	On-farm resources	100 - 500	20,000 - 100,000
Extensive	On-farm resources, fertilizers	100 - 1000	10,000 - 100,000
Improved extensive shrimp (India)	Supplemental feeds	3240	5543
Semi-intensive	Supplemental feeds, static	2,000 - 8,000	1,250 - 5,000
Semi-intensive	Supplemental feeds, water exchanges	4,000 - 20,000	500 - 2,500
Semi-intensive	Supplemental feeds, water exchanges, night aeration	15,000 - 35,000	300 - 700
Intensive	Complete feeds, water exchanges, night aeration	20,000 - 50,000	200 - 500
Intensive	Complete feeds, water exchanges, constant aeration	20,000 - 100,000	100 - 500

In addition to the physical space occupied by the facility, land is required to produce plant meals and oils for aqua feeds. Corn meal, soybean meal, peanut meal, cottonseed meal, wheat middlings, rice flour, and vegetable oils are common plant products used in aqua feeds. Cottonseed meal and wheat middling are by-products of cotton fibre and wheat flour production. Vegetable oils are extracted from soybeans, peanuts, corn, and other seeds in the process of making meals. Their use in aqua feeds usually does not require land dedicated specifically for production. Land must be dedicated specifically for the production of corn, soybean, peanut, and certain other plant meals used in aqua feeds.

In addition to land area for facilities and to produce food, ecosystem area is needed to assimilate wastes produced during aquaculture. In ponds and recirculating systems, significant quantities of waste produced during culture are treated within the facility, and there is relatively little external area needed for waste treatment. On the other hand, much of the waste produced in raceway and net pen culture is discharged directly to the outside environment. The ability of the external ecosystem to assimilate those wastes may limit aquaculture production either by polluting the surrounding water to the point where animal welfare inside the facility is endangered (“self-pollution”) or by imposing limits to the amount of waste that can be discharged due to regulatory constraints. In addition to effects on aquaculture production, waste discharge into public waters creates societal externalities such as degraded water quality, water treatment costs, and other downstream impacts. However in this study we do not estimate land requirement for feed ingredient production or effluent water treatment.

5.5 Energy use

There are many uses of energy in aquaculture including energy used for construction of facilities, production of liming materials, fertilizers, production and transport of feed and feed ingredients, operation of machines and vehicles during culture and harvesting, processing, transportation, etc. However, only two of these energy inputs can be readily estimated at the farm level. These are energy uses for pumping water and for mechanical aeration, and, at the farm level, they are the major, direct energy inputs. This discussion will be limited to pumping and aeration, but studies of total energy use per tonne of aquacultural production should be conducted for a number of species and culture methods.

Mechanical aerators powered by internal combustion engines or electric motors are used to supplement the natural supply of dissolved oxygen in grow-out systems. Aeration allows greater stocking and feeding rates to increase production. Aeration rates in pond aquaculture often are expressed in horsepower per hectare or horsepower applied per volume (Boyd and Tucker, 1998). In channel catfish farming, aeration usually is applied at 4 to 8 hp/ha, while in intensive marine shrimp culture, rates of 10 to 30 hp/ha may be applied. Use of electricity typically is measured in kilowatt·hours (kW·h), and 1 hp = 0.745 kW. However, there are inefficiencies in the use of electricity by machines, and for aerators, the typical efficiency is about 90% (Boyd, 1998). Thus, electricity use for aeration can be estimated as follows:

$$\text{Aeration energy, kW} = \frac{\text{Aerator power, hp} \times \text{Aeration time, hr} \times 0.745\ \text{kW/hp}}{\text{Production, t} \times 0.9}$$

Aerators in channel catfish ponds in the south eastern United States normally are operated between May and September for about 10 h/night. Aeration at 6 hp/ha in a catfish pond will use 7,599 kW·h of electricity during a crop year or about 950 kW·h/t for production of 8,000 kg/ha. Production of marine shrimp in a pond with 15 hp aeration/ha might be 8,000 kg/ha for a 120-day crop. In Asia, paddlewheel aerators often are driven by small, internal combustion engines powered by diesel fuel or gasoline. Energy use can be estimated from fuel consumption; 1 L diesel fuel is equal to 3.27 kW-h while 1 L of gasoline equates to 2.21 kW-h (Yoo and Boyd, 1994).

The energy use for pumping water to supply ponds can be estimated as follows:

$$P = \frac{\gamma Q H}{E}$$

Where,

P = power required by pump (kW),

γ= specific weight of water (9.81 kN/m3),

Q = discharge (m3/sec), H = pumping head (m), and

E = pump efficiency (decimal fraction).

Boyd and Tucker (1995) used this equation and water management data to estimate that about 1,275 kW·h of electricity typically would be used to fill a 1-ha channel catfish ponds. Annual energy use for pumping water to maintain water levels would be less than 500 kW·h in humid climates and up to 2,000 kW·h in arid climates. Assuming total energy use of 1,775 kW·h//ha per year for catfish ponds in a humid climate, the energy use for pumping would be about 296 kW·h/t as compared to 950 kW·h/t for aeration.

In semi-intensive shrimp culture, ponds are about 1.2 m deep and water often is exchanged at 5% of pond volume daily. The average lift for the water is 3 m. The pump discharges 3 m^3/sec at 85% efficiency, and from Equation 16, the pump power is 103.9 kW. Initial filling of ponds for each crop will require 12,000 m3/ha of water and the water exchange requirement is 64 m^3/day. The energy requirement for Indian case study was 4358 MJ/ton and was benchmarked against other estimates of energy in Table 25.

Table 25. Efficiencies of energy use for aquaculture system. Adapted from Costa-Pierce

Food Systems	Production (MT/ha)	MJ/MT	References
Canada Salmon Net Pen Water-Based	1,000	26,900	Ayer and Tyedmers (2008)
Canada Salmon Bag System Water-Based	1,733	37,300	Ayer and Tyedmers (2008)
Canada Salmon Flow-through Land Based	2,138	132,000	Ayer and Tyedmers (2008)
Canada Salmon Recirculating Land-Based	2,406	233,000	Ayer and Tyedmers (2008)
Shrimp case study, India	1200	4358	Aquaclimate

Studies using modified LCA methodology consistently show that the energy used to produce aquafeeds dominates the energetics of aquaculture production. For example, more than 75% of the total energy cost of producing Atlantic salmon in net pens is used in procuring or growing feed ingredients and manufacturing the feed (Folke, 1988; Troell et al., 2004; Tyedmers, 2004; Ellingsen and Aanondsen, 2006). The remaining energy inputs, in order of importance, were fuel and electricity used to operate the facility, embodied energy costs (manufacture, maintenance, etc.) associated with physical infrastructure, and energy used to produce smolts). Feed production dominates the energy budgets of all aquaculture systems relying on aquafeeds, regardless of species (Troell et al., 2004).

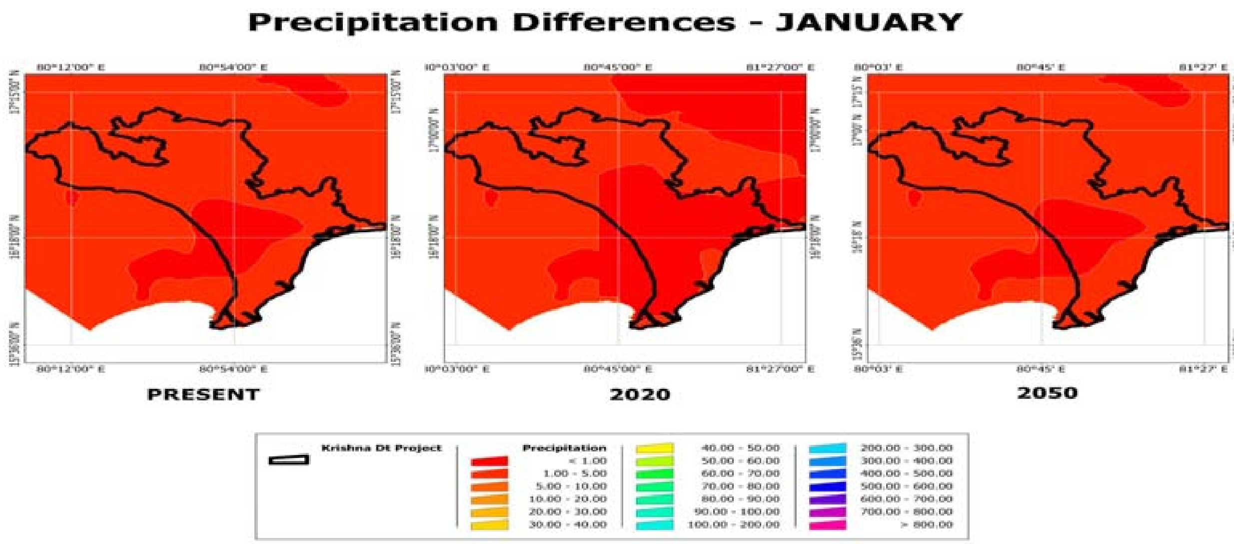
Life-cycle assessment of energy use can include post-harvest functions such as processing, freezing, refrigeration, storage, transportation, marketing, waste treatment, and even household activities such as refrigeration, freezing, and cooking. Energy use in these activities apparently has not been assessed for aquaculture but may be an important part of the overall energy costs of delivering aquaculture products to a consumer's plate. For example, energy used in on-farm production of the United States food supply accounts for only about 20% of the energy used to deliver food to the consumer's plate (Heller and Keoleian, 2000). Post-harvest processing and transportation each consume about 15% and household preparation accounts for more than 30% of the total energy consumed. Ultimately, it will be economically and socially imperative to improve the energy efficiency of all aspects of the food-supply chain. However, it is possible that greater overall gains in energy savings can be made by improving the efficiencies of processing, transport, retailing, and even household storage and preparation than can be made by improving energy efficiency in the production sector. This may have particular relevancy in aquaculture, where important products are produced only in certain regions (marine shrimp in the tropics; salmon in the north-temperate) and are stored and shipped long distances for ultimate consumption. Energy comparisons between systems have become part of more detailed analyses of life cycles (Papatryphon et al., 2004; Ayer and Tyedmers, 2008). Comparisons of these with terrestrial farming show clearly the huge production benefits of intensive aquaculture albeit at a much higher energy cost, contained mostly in feed (Ayer and Tyedmers, 2008). Over the coming decades, increasing global energy, processing, shipping/transportation costs of both products and feeds are predicted (FAO, 2008; Tacon and Metian, 2008).

In the present study, the use of energy on the farm was only considered. Global warming potential is mainly contributed to the use of compound feed in feed production at the feed mill as well as the use of electricity in aerators at the shrimp farm. With respect to the feed production, the use of fish meal contributed dominantly to the GHG emissions. Global warming potential (GWP) and eutrophication potential (EP) values for the present shrimp culture case study were 3,920 kg CO_2e and 0.629 kg PO_4-e per ton shrimp production. However, the level of GHG emissions of Indian shrimp is lower than Chinese shrimp and French trout, but higher than Canadian salmon, Norwegian salmon, Indonesian tilapia, Vietnamese Pangasius catfish, and Filipino milkfish. Thus, the feeding management and the optimal operation of aerators must be given the attention in order to reduce the GHG emissions. More importantly, the potential impacts associated with feed ingredients especially fish meal and wheat flour should be taken into account at the feed mill. The energy performance of aerators used should also be considered at the farm, i.e. aerators with high-energy efficiency are preferred with the monitoring of optimal level of oxygen in ponds. Another considerable factor affecting to the potential impacts of aquaculture systems are related to the quality of seed which is linked to the farm productivity (though the impacts from seed production itself is rather low) and therefore the GWP values.

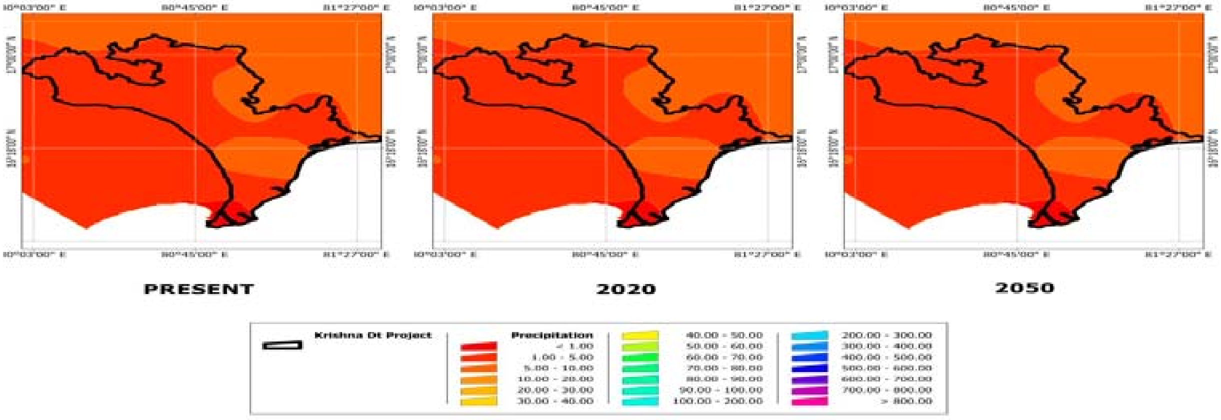
6. Predicted climate change 2020 and 2050

6.1 Precipitation scenarios differences in present and Future Scenarios (2020-2050) in Krishna District, Andhra Pradesh

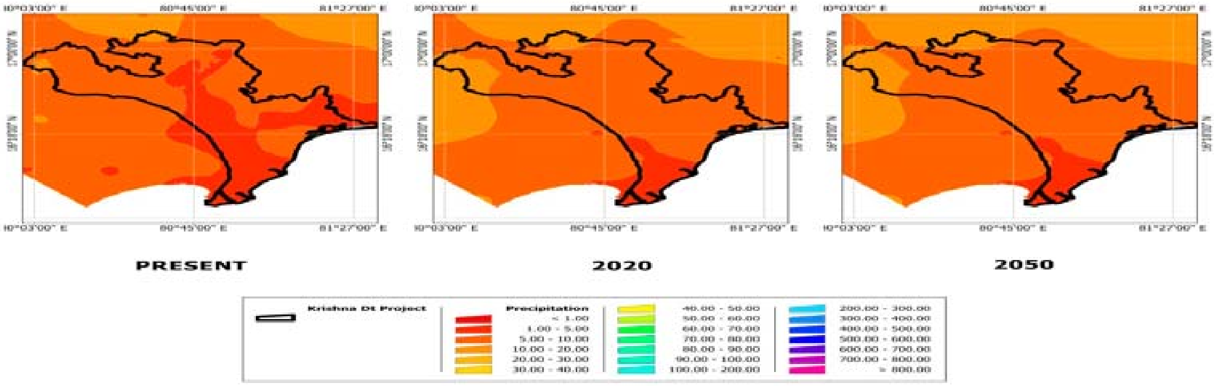
A simulation of projected changes in January-December precipitation from the period of current year to the period of 2020 to 2050 is presented in Fig.17. Different sets of scenarios were developed to cover the possible range of impacts, incremental and General Circulation Models (GCM) based. In applying the GCM results. The present climatologically data have changes added and in terms of average precipitation changes anticipated by 2020. The greatest precipitation (relative to current year) is expected in western NE and the SE of more precipitation projected for the southern and coastal areas. But it is not evenly distributed geographically. There are marked regions of decreasing, as well as increasing precipitation, over both land and ocean. In January month though not much significant was observed there were also differences between the GCM precipitations scenarios concerning the location of the area of maximum precipitation increase 2020. The February month pattern has been expected to experience the normal precipitation. On average, precipitation will increases in the month of March. In April there is not much contrast between modelled and observed precipitation in the magnitudes and even the directions of the differences. The precipitation differences in the month of May showed that steadily increase along eastern coast of Krishna district. The greatest precipitation changes are anticipated in 2020 likewise 2050. The month of July precipitation scenarios predicted less precipitation by 2020 than current projection. In the month of August there has been a medium-resolution interpolation of the GCM on Krishna river basin. There is no significant of precipitation either decrease or increase in the month of September to the present and future. For October there is indicated increase in the northeast of the Krishna river basin and the southwest, with an axis of precipitation reduction from the northwest to the southeast across the centre of the Krishna district except for precipitation of 2020. The precipitation changes for the present and future scenarios (2020 and 2050) are spatially homogeneous in the month of December.



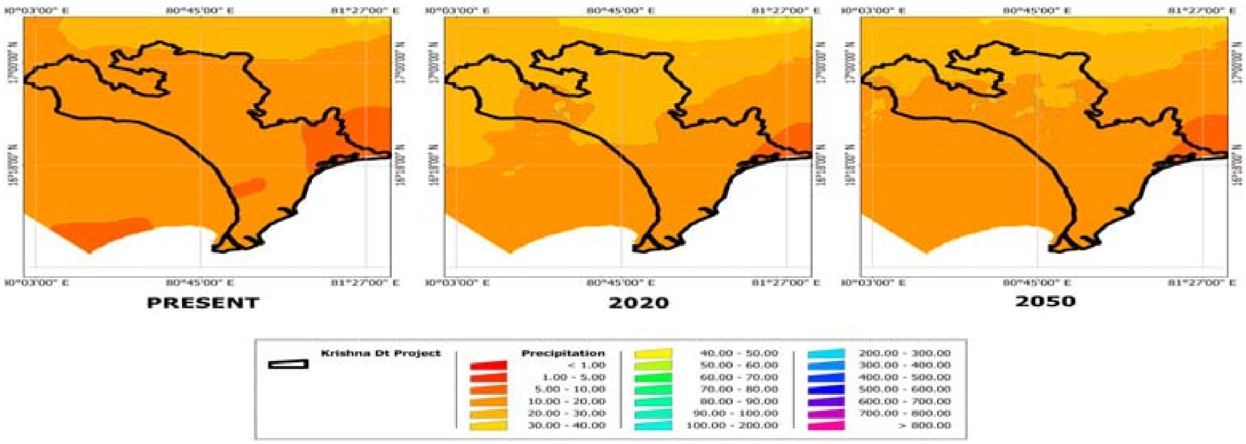
Precipitation Differences - FEBRUARY



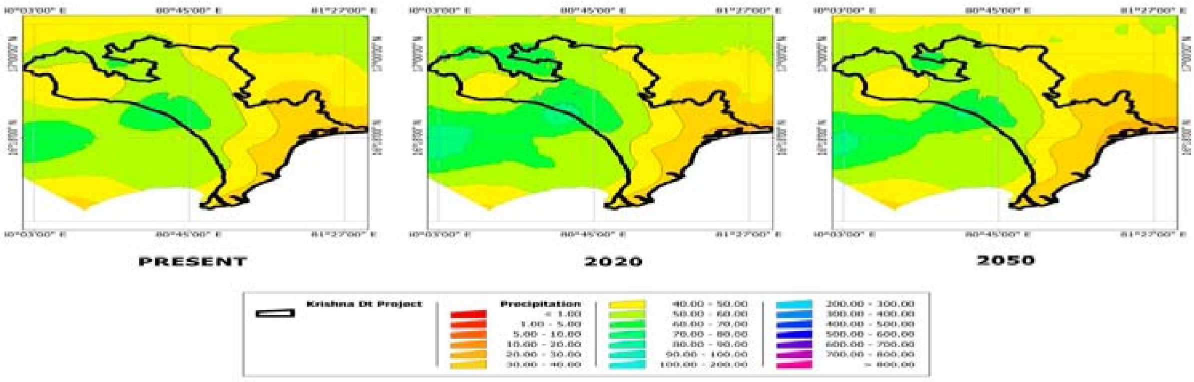
Precipitation Differences - MARCH



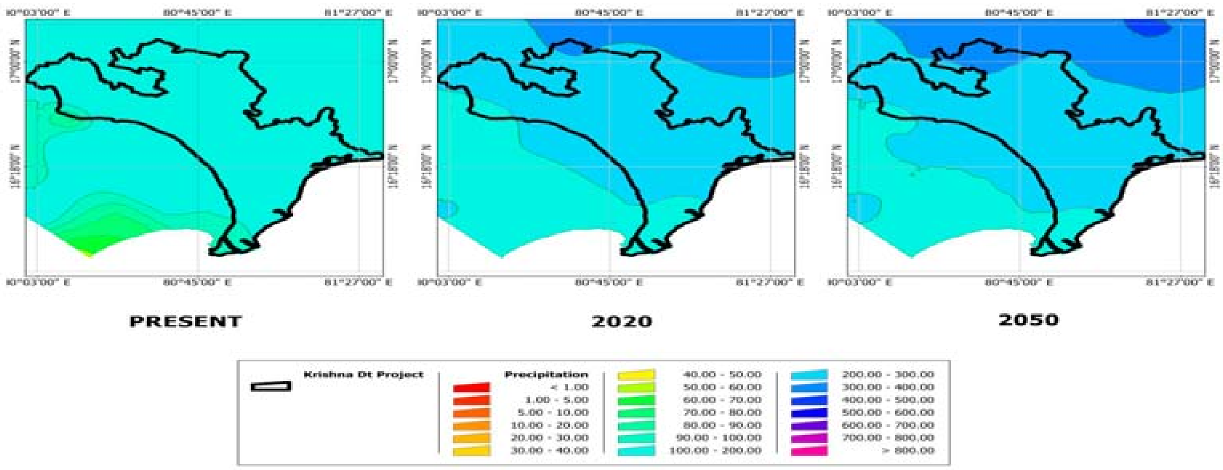
Precipitation Differences - APRIL



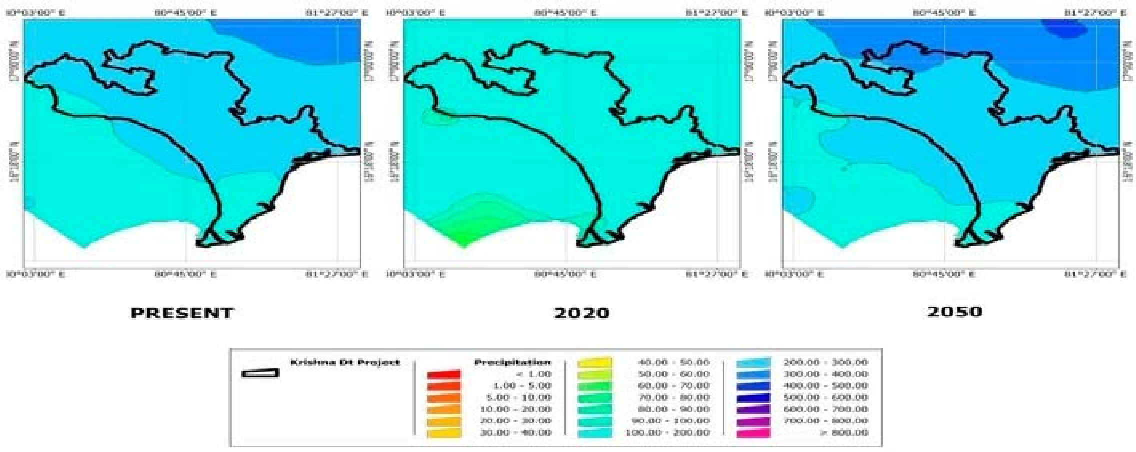
Precipitation Differences - MAY



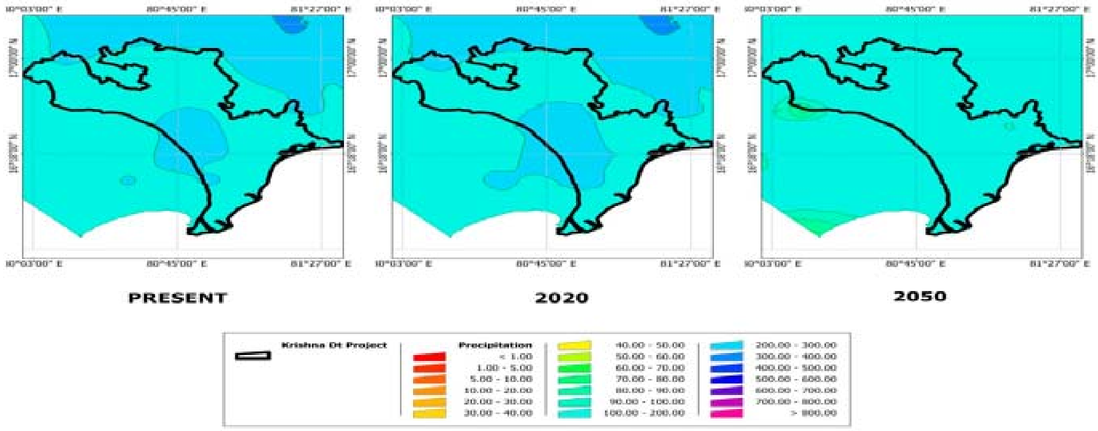
Precipitation Differences - JUNE



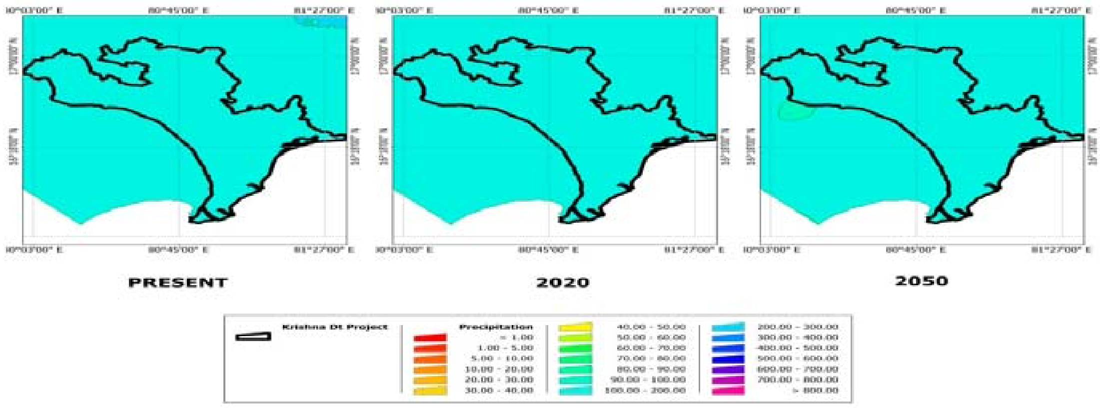
Precipitation Differences - JULY



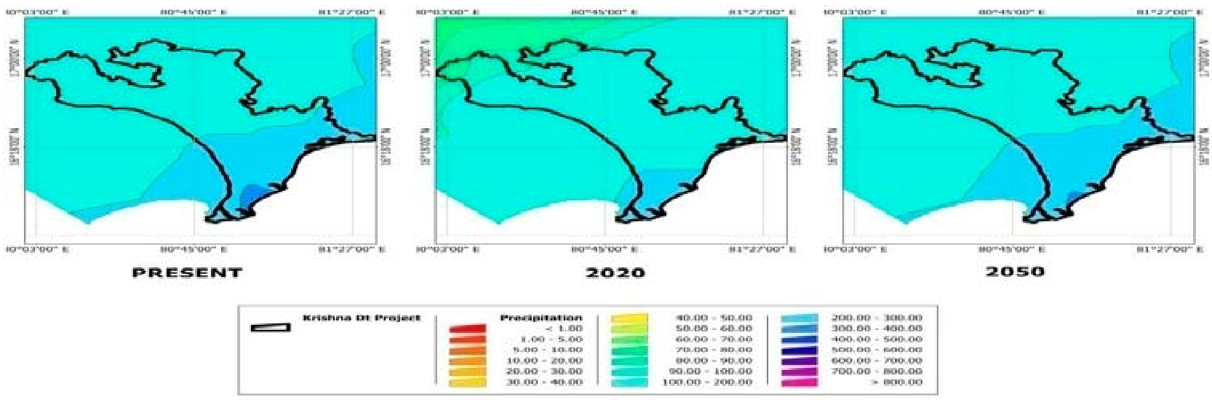
Precipitation Differences - AUGUST



Precipitation Differences - SEPTEMBER



Precipitation Differences - OCTOBER



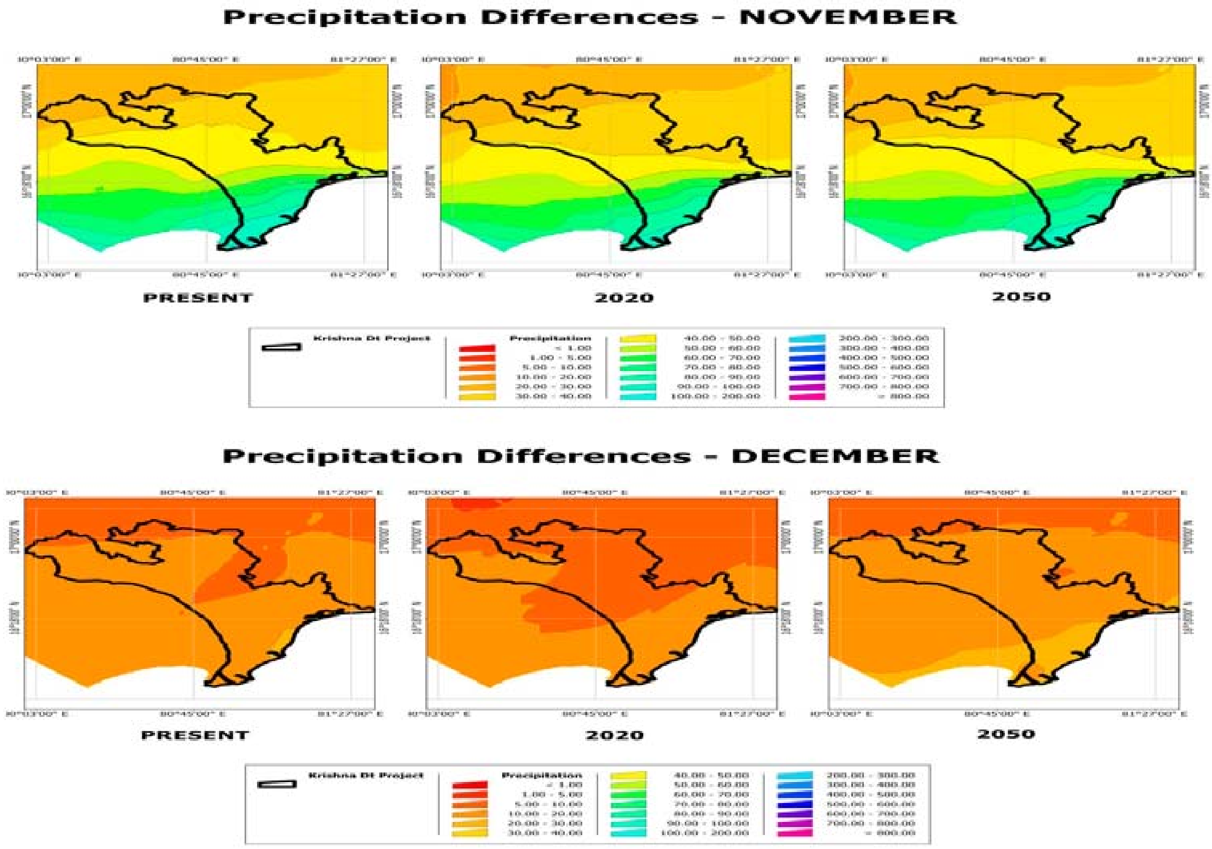


Fig.17. Precipitation scenarios for the present and future (2020 and 2050)

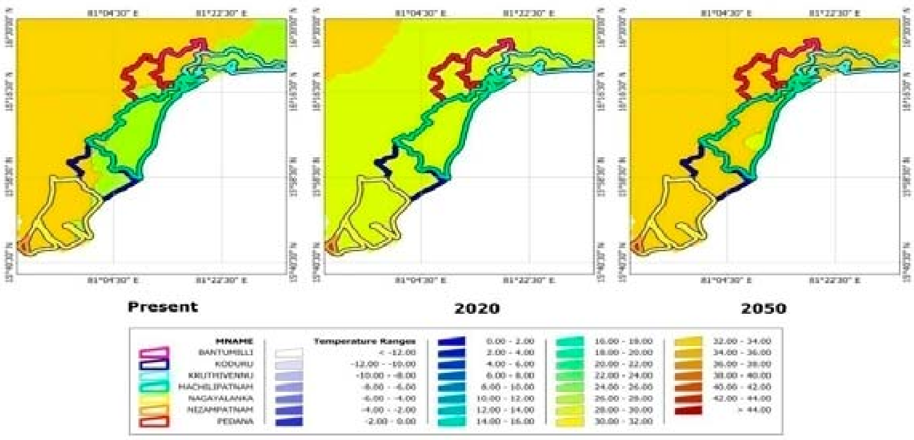
6.2 Maximum temperature differences in present and Future Scenarios (2020 and 2050) in Krishna district, Andhra Pradesh

The changes in average temperature predicted by the GCMs are always positive, and show high magnitudes and marked spatial patterns, with the predictor variables accounting for maximum of the explained variance with present and future scenarios (2020-2050). Figure 18 shows that the mean changes in future scenario temperature tended to be <2 °C in present January month. Though it is statistically significant, the main difference between the future temperature scenarios is that the main difference is connected to inversion-exposed inland areas. The physical reason is that mild winters have been associated with weather conditions that are unfavourable for ground inversions, i.e. more cyclone activity and consequently more cloudy and windy conditions. Besides, the smog cover on the Krishna river basin have probably been less persistent in mild winters, contributing to a positive feed-back on the temperature, while the smog cover in the Krishna river belt has been persistent even during mild winters.

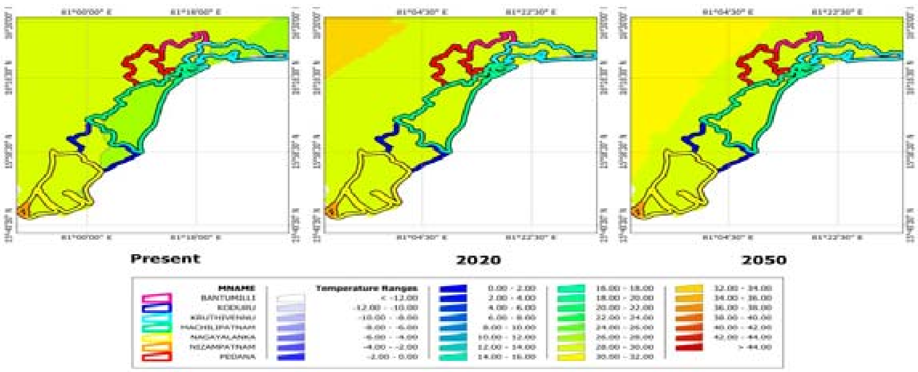
Mean GCM surface temperatures also appear to be more realistic output when compared to the observed historical climatology. The geographical patterns of surface temperature differences during the monsoon season between the 2020-2050 periods are again well comparable between raw GCM outputs. Maximum surface temperatures changes for all watersheds are found during the dry season most particularly in February-March. Again, the dispersion between the GCMs projected changes remains substantial even if less pronounced than for precipitation. Nevertheless, in the case of May month, GCM output exhibit larger changes for the current scenarios than for the period 2020-2050 when compared to the historical period. Maximum temperature increases are found in both cases from north western regions towards the eastern coast of Krishna district.

It was noted on the month of June temperature scenarios will be expected higher level from the mean GCM downscaled analysis. Smaller variations are found during the monsoon season with minimum changes in July, August, September and October. When compared to the observed climatology, the projected temperature patterns found in all GCMs downscaled data is far more coherent than raw GCMs surface data in particular regarding the latitudinal gradient along the east coast and the gradient inland.

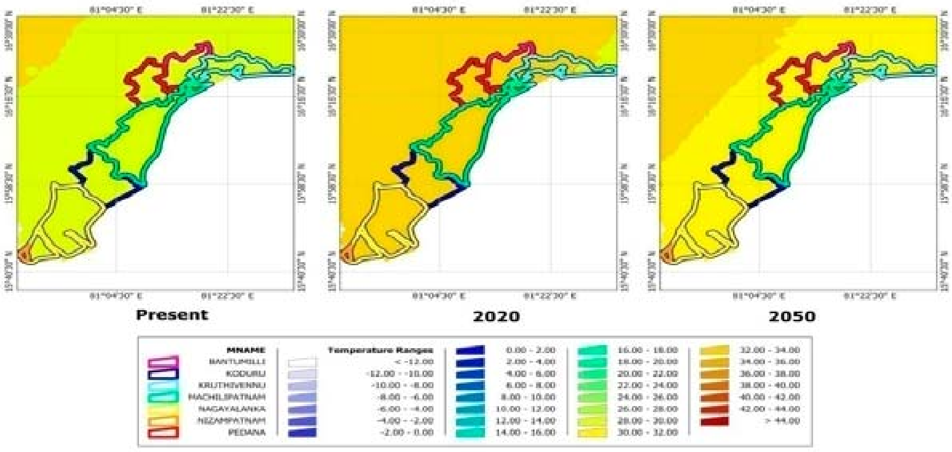
Temperature-Maximum Differences - DECEMBER



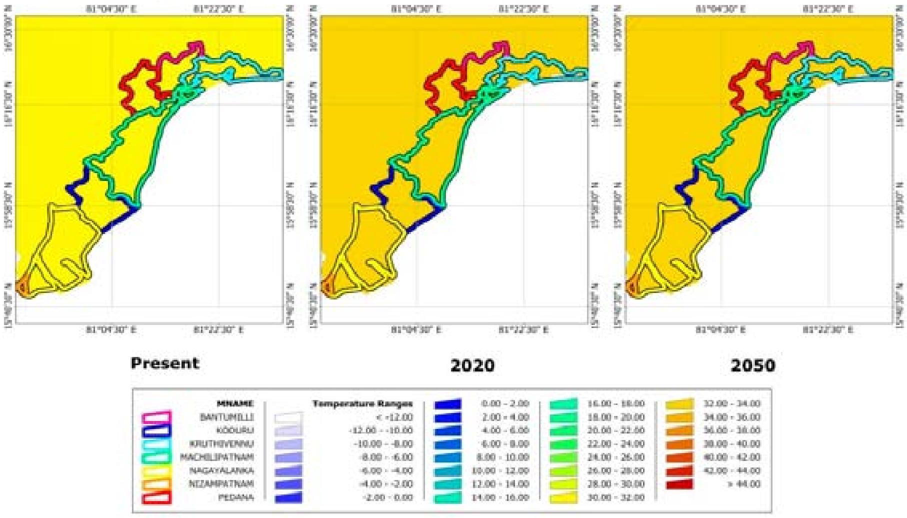
Temperature-Maximum Differences - JANUARY



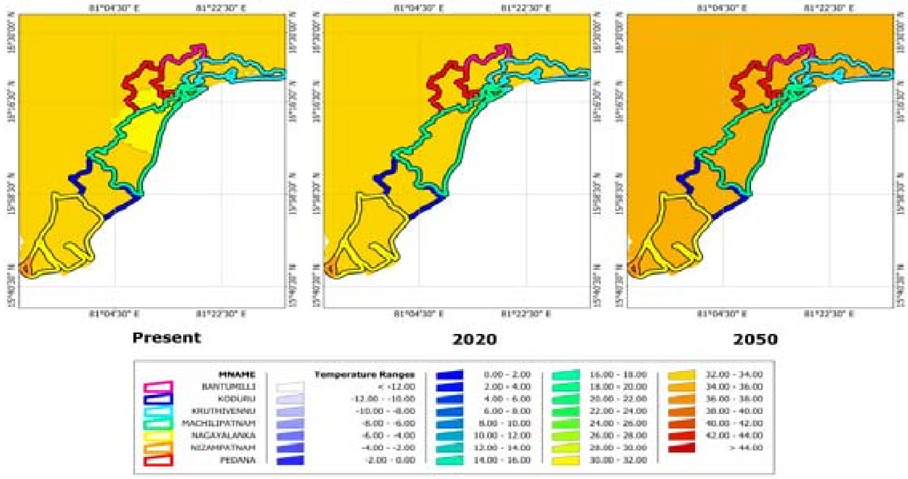
Temperature-Maximum Differences - NOVEMBER



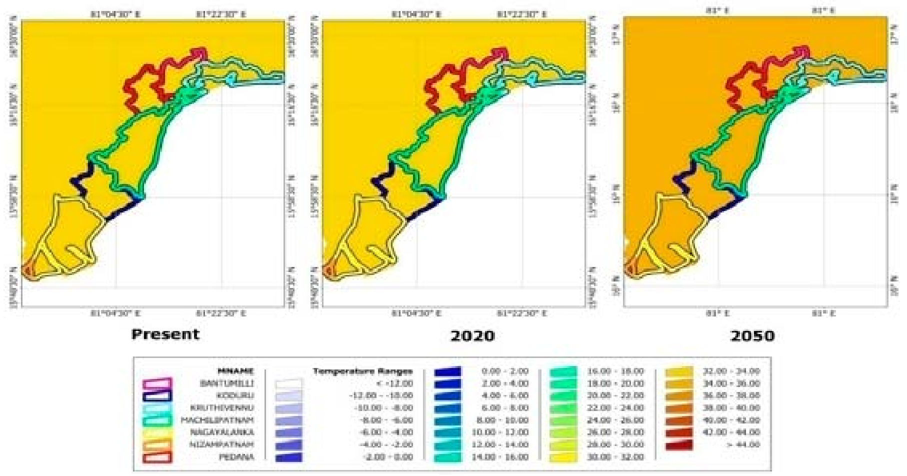
Temperature-Maximum Differences - OCTOBER



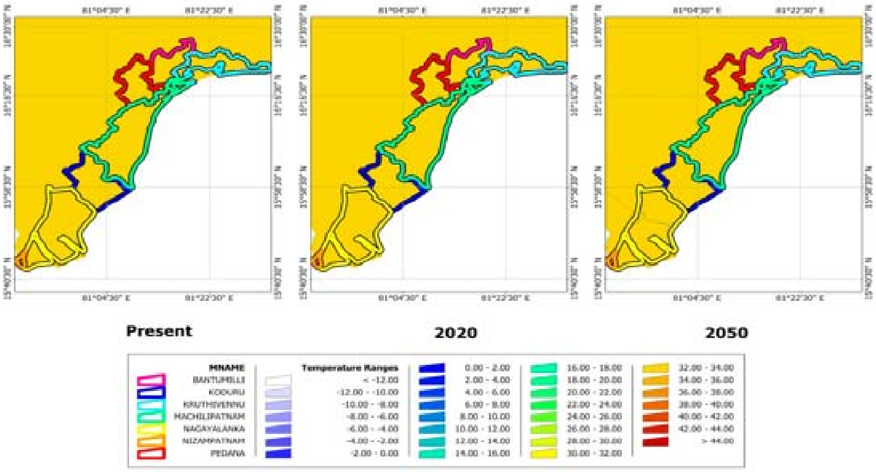
Temperature-Maximum Differences - SEPTEMBER



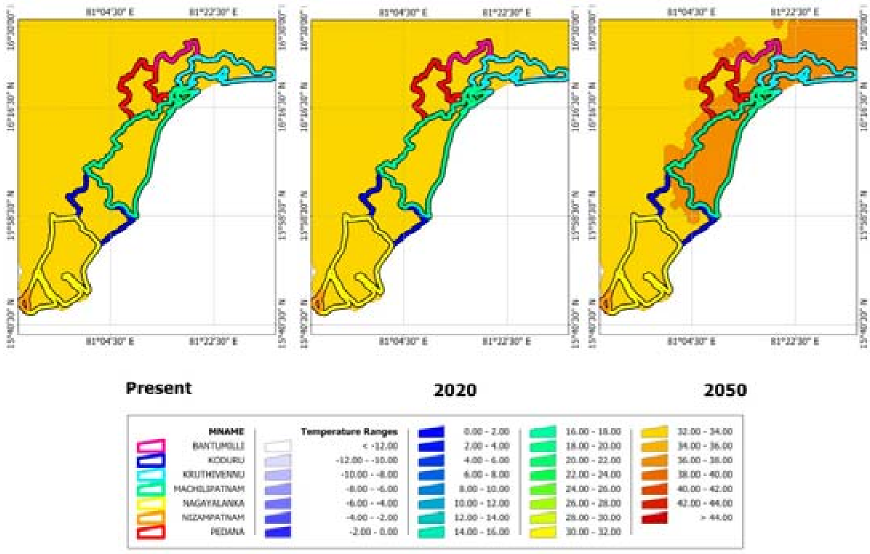
Temperature-Maximum Differences - AUGUST



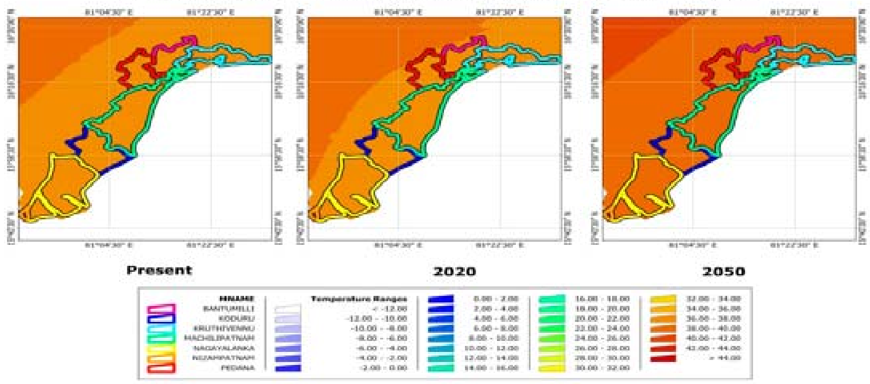
Temperature-Maximum Differences - JULY



Temperature-Maximum Differences - JUNE



Temperature-Maximum Differences - MAY



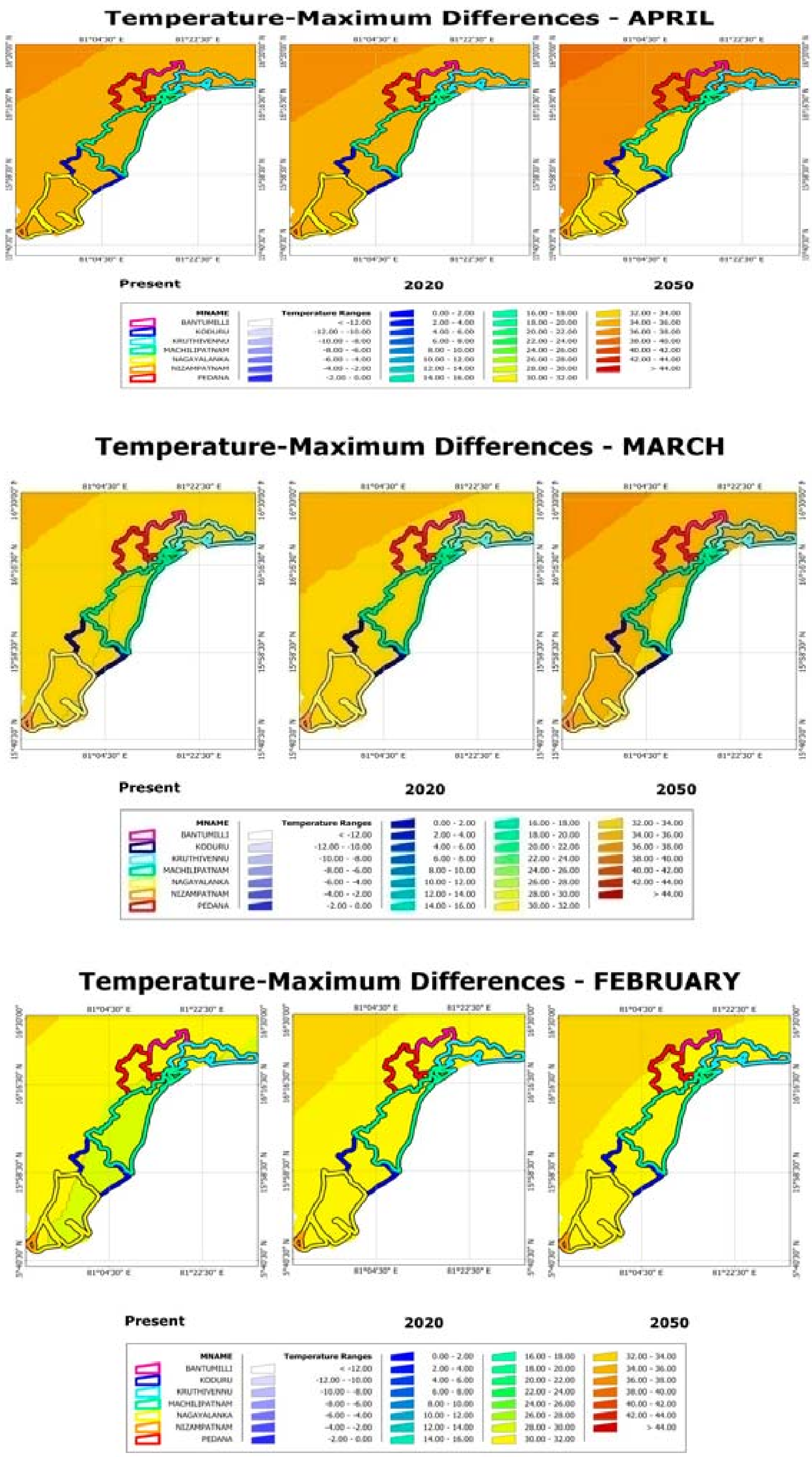
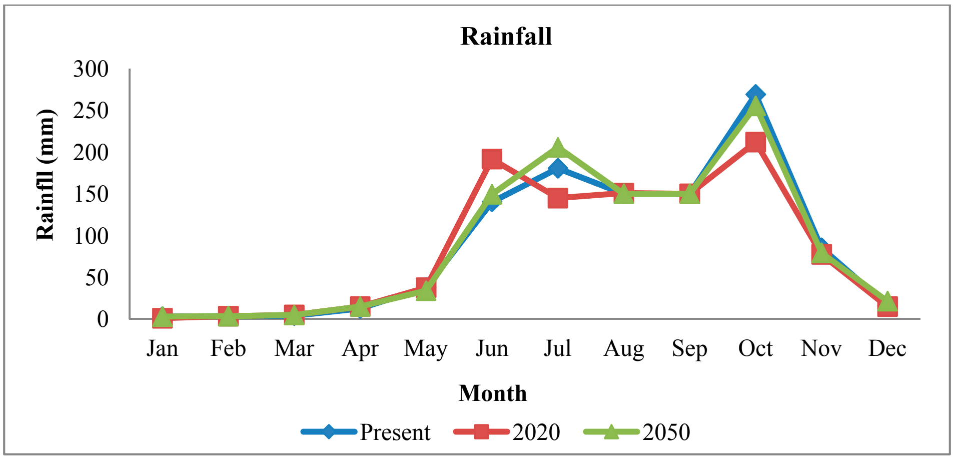


Fig.18. Maximum temperature differences for predicted climatic scenarios for the present and future (2020 and 2050)

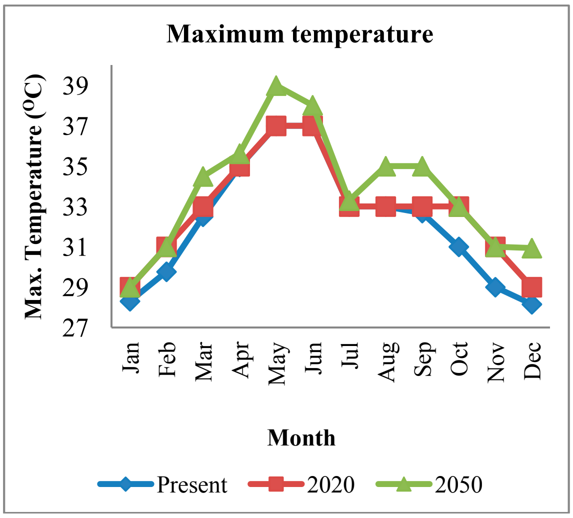
Month-wise climate change predictions in 2020 and 2050

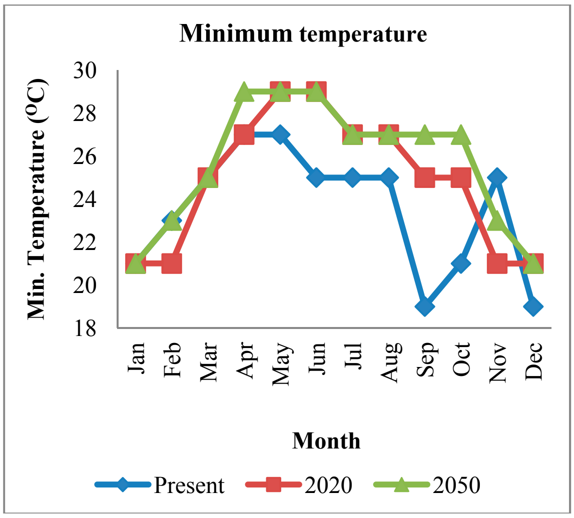
In brief, month-wise climate predictions in 2020 and 2050 compared to the present values is described here. Rainfall and temperature scenarios are based on simulated changes averaged over two broad seasons, the southwest and the northeast monsoons. In the study area there is not much difference in average monthly rainfall from the present to the predicted scenarios during January to May, and August, September, November and December months in 2020 and 2050. There will be a decrease in rainfall during July in 2020 compared to the present value and increase in 2050, whereas increase in rainfall compared to the present value is predicted during June in 2020 and 2050. Peak rainfall was observed (269 mm) in the month of October at present and the predictions showed a decreasing trend during 2020 and 2050. It is assumed that probability of rainfall distribution will be 13% less in the month of October. The decrease in rainfall during July and October will not have any adverse effect on shrimp aquaculture for the farmers practicing zero water exchange.



Average maximum temperature scenarios predicted in the study area suggest that temperature would increase throughout the region. The maximum temperatures will increase by 1-2 ˚C by 2020 and 2050. There will also be hot weather spells for longer periods. The present peak average temperature, which occurs in May to June, will be extended for two and a half months in 2020 and 2050 which poses significant risks. The prediction showed that average maximum temperature of 39^{0}C during May in 2050. However, there may be differences within the region, depending on proximity to the sea with the warming more pronounced in coastal part of Krishna district. Since there will not be much change in rainfall, the increase in temperatures will have adverse effect on the water availability in source waters, changes in water quality parameters thus affecting the shrimp growth performance.

Predictions over study area indicated that the mean monthly minimum temperature will increase by 2-4°C in 2020 and 2050 comparative to the present scenario. Prediction showed that, while the lowest minimum temperature is expected to be warmer by more than 2^{0}C over the study area. The increase in temperature during winter months will be positive for shrimp farming leading to better food conversion rate and faster growth rate.


Maximum temperature
Max. Temperature (°C)
39
37
35
33
31
29
27
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Present
2020
2050


Minimum temperature
Min. Temperature (°C)
30
28
26
24
22
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18
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Nov
Dec
Month
Present
2020
2050

7. Recommended adaptation measures for future (2020 and 2050) predicted Climate

Tiger shrimp pond farmers are highly vulnerable to climate change, as production is highly influences by the weather. They are affected by changes in the normal weather plans. They are located on low lying land close to river estuary and the coast and susceptible to flooding and sea level rise. They are prone to extreme events such as heavy rains, strong winds and changing climate conditions such as increased temperatures and changing precipitation patterns. They are not only losing yields due to these climatic impacts but it is also affecting the quality of their produce.

As farmers, they have developed mechanisms to cope with small changes in the weather patterns but they are not prepared for quick changes in seasonality or extreme events which can hit farmers hard, leading to crops not giving the expected output, reducing productivity and thus family income. Farmers are further more vulnerable to environmental and economic risks due to the lack of money and capacity to adapt.

The adaptive measures are presented in this chapter present adaptation measures by farmers to perceived climate changes already taking place from the outcome of questionnaire survey and the potential adaptation measures to future predicted climate changes in 2020 and 2050.

7.1 Present adaptation measures

The adaptive measures followed by the farmers against each climate change are shown in flow chat (Fig.19). The most important adaptation measures are water exchange, feeding practice, lime application, adjusted harvest and delayed stocking for irregular season, high temperature and uneven rainfall distribution. Dyke height increase, shifting of machineries, netting around the farm, shifting to other occupation are the adaptive measures for cyclones/storm surges and flood, and freshwater mixing for drought. The value in parentheses indicated the percent of farmers implementing the particular adaptive measure for each climatic change event.

Grouping of farmers based on their affiliation to society and location **Significant adaptation measures for various CC**	**Society (247)**	**Non-Society (53)**	**Coastal area (240)**	**Inland area (60)**
Water exchange	IRS (59.3), HTEM (81.9)	IRS (15.2), HTEM (20.2)	IRS (56.8), HTEM (80.2)	IRS (17.7), HTEM (21.8)
Feeding practice	IRS (41.2), HTEM (72), HR (44)	IRS (12.8), HTEM (16.9), HR (6.2)	IRS (44.9), HTEM (70.4), HR (36.2)	IRS (9.1) HTEM (18.5), HR (14)
Lime application	IRS (58)	IRS (13.6)	IRS (51.9)	IRS (19.8)
Adjusted harvest	IRS (55.6), HR (10.3), FLD (4.5)	IRS (11.9), HR (2.9), FLD (3.7)	IRS (51.4), HR (10.7), FLD (5.3)	IRS (16), FLD (2.9), HR (2.5)
Delayed stocking	HR (25.1), FLD (11.5)	HR (8.6), FLD (4.5)	HR (25.5), FLD (11.9)	HR (8.2), FLD (4.1)
Dyke height increase	HR (56), FLD (97.9), CYC (98.8)	HR(9.9), FLD (23), CYC (23.5)	HR (49), FLD (96.7), CYC (98.4)	HR (16.9), FLD (24.3), CYC (23.9)
Shifting of machineries	CYC (40.7), HR (60.1), FLD (95.9)	CYC (7.8), HR (7.8), FLD (22.2)	CYC (37), HR (51), FLD (95.1)	CYC (11.5), HR (16.9), FLD (23)
Netting around the farm	CYC (15.2), HR (38.7), FLD (34.6)	CYC (4.5), HR (7.4), FLD (5.8)	CYC (17.7), HR (34.6), FLD (31.3)	CYC (2.1), HR (11.5), FLD (9.1)
Shifting to other occupation	HR (7.4), FLD (7.8), DRT (32.9)	HR (0.4), FLD (0.4), DRT (3.7)	HR (2.5), FLD (6.2), DRT (28.8)	HR (5.3), DRT (7.8), FLD (2.1)
Freshwater mixing	DRT (30.9)	DRT (3.7)	DRT (25.9)	DRT (8.6)
Planned adaptation	FLD (11.5), CYC (9.5)	FLD (4.9), CYC (2.5)	FLD (12.3), CYC (9.1)	FLD (4.1), CYC (2.9)

Fig. 19. Flow diagram showing the perception of CC events and significant adaptive measures by shrimp farmers in Andhra pradesh.
(IRS – Irregular season; HTEM - High temperature; CYC – Cyclones; HR -Heavy rains; FLD – Flood; DRT – Drought)

7.1.2 Adaptive measures and their estimated level of success

Farmers are following different types of adaptive measures for each CC event. The adaptive measures and the adaptation cost were compared with the level of success.

(i) Irregular season

Water exchange, feeding practice, lime application, adjustable harvesting and delayed stocking were the adaptive measures reported by farmers to cope up with the losses due to IRS. Water exchange was significant with level of success in all the categories of farmers, and the order of success was more in inland area. Feeding practice was not significant with non-society and inland farmers. Lime application and post stocking were not significant, where as adjustable harvesting was significant in all the categories except inland. Among all the measures water exchange was highly correlated with level of success.

(ii) High temperature

All the three adaptive measures viz., water exchange, feeding practice and lime application including the adaptation cost are significant with level of success. Lime application was the most significant measure followed by feeding practice and water exchange. The level of success was more correlated with non-society farmers with lime application (Table 8). Society and coastal area farmers practiced water exchange and feeding practice, where as lime application was followed by all the farmers.

(iii) Cyclone

Shifting of infrastructure and materials in the farm, delayed stocking, adjustable harvesting, netting around the farm and the assistance from the Government are only the significant adaptive measures for CYC. 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. The cost involved in implementing the adaptive measures is not significant with the level of success. The percent of non-society and inland area farmers implementing the adaptive measures was very low compared to coastal and society farmers.

(iv) Heavy rain

All the adaptive measures viz., increasing the dyke height, delayed stocking, feeding practice, material shifting, netting around the farm, adjustable harvesting and shifting to other occupation were significant with the level of success. The percent of farmers implementing the adaptive measures was more in coastal and society farmers. Adaptation cost was not correlated with the level of success.

(v) Flood

Similar adaptive measures that were followed in case of heavy rains besides Govt. help were reported by the farmers for FLD. Except material shifting all the other adaptive measures were correlated with level of success. Netting around the farm was highly successful adaptive measure compared to the others.

(vi) Drought

The two adaptive measures viz., shifting to other occupations and freshwater mixing had significant relationship with level of success and both were rated equally important. However, the adaptation cost was not correlated with the level of success. The percent of farmers implementing these adaptive measures were more in coastal area and society farmers.

7.1.3 Adaptation measures cost variation among CC types

There was a significant difference between CC type and the average adaptation measures implementation cost. Maximum adaptation cost was observed for CYC followed by FLD and IRS for society and coastal farmers, whereas it was in the order of CYC, FLD and HR for non-society farmers and HR, FLD and CYC for inland farmers (Table 25).

7.2. Adaptive capacity of farmers

In order to assess the adaptability of farmers they were asked to rank the different factors that have contributed to their current level of vulnerability/resilience and their capacity for adaptation.

7.2.1 Technical improvements in the adaptive measures to overcome CC

All the categories of farmers ranked the requirement of financial support, insurance and relief fund in case of extreme climatic events as the first priority. Society farmers ranked participation of farmers in climate change management as the second and training awareness as the third, whereas for non-society farmers the order was reversed (Fig.20). This might be due to the training and technical advices provided by NaCSA and involvement of farmers in FGD and SH workshop on climate change.

Table 25. Difference between adaptation measures cost for climate change types

CC type	All farmers	Society farmers	Non-society farmers	Coastal farmer	Inland farmer
Irregular season	1200-18000 (2642[e]±4440)	1200-18000 (2951[e]±4914)	1200-2000 (1397[bc]±236)	1200-18000 (3024[e]±4980)	1200-1800 (1323 [b]±177)
High temperature	1000-3300 (1830[cd]±425)	1250-1300 (1838 [d] ±438)	1000-3000 (1795[c]±367)	1000-3000 (1873[d]±410)	1250-3300 (1671 [c]±445)
Cyclone	1300-15000 (3757[g]±2230)	1300-15000 (3549 [f] ±1981)	2600-15000 (4646[f]±2930)	1300-15000 (3914 [g]±2407)	1300-6500 (3130 [e]±1102)
Heavy rain	1300-6000 (2859[d]±1542)	1300-6000 (2915 [e]±1545)	1300-6000 (2626.0[d]±1524)	1300-6000 (2682[e]±1479)	1300-6000 (3575 [f]±1595)
Flood	2000-6000 (3316[f]±1198)	2000-6000 (3230[e]±1191)	2000-6000 (3680[e]±1167)	2000-6000 (3254 [f]±1194)	2000-6000 (3561[f]±1190)
Drought	1000-2000 (248[a]±538)	1000-2000 (255 [a] ±534)	1000-2000 (214 [a]±568)	1000-2000 (244 [a]±543)	1000-2000 (266[a]±520)

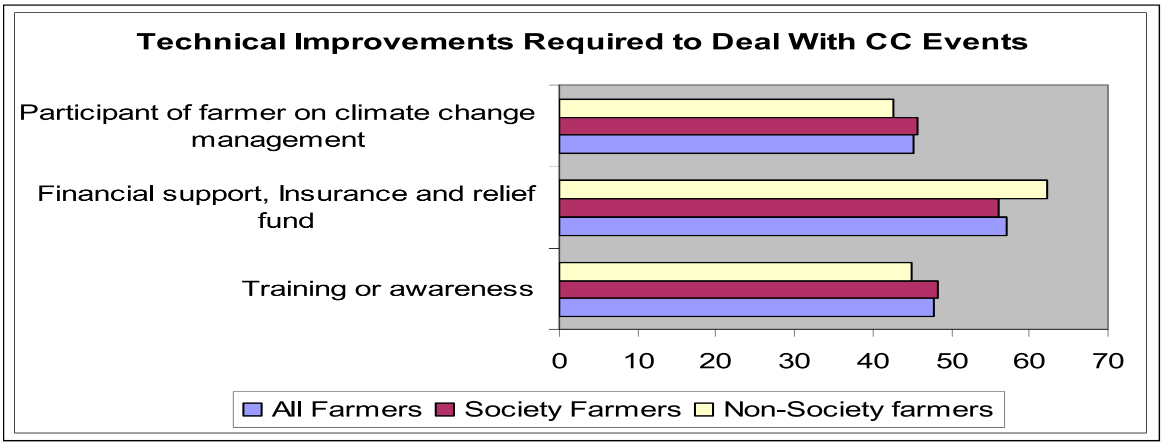

Fig.20. Technical improvements in the adaptive measures to overcome CC events

7.2.2 Support received from different agencies

Regarding the type of support received from the government agencies farmers ranked technical support as the first followed by material (post larvae, feed, equipment), training (skills development) and financial support (grants, subsidies, loans). The agency that was most capable to give the support to shrimp farmers was NGO followed by Govt., farmers group and research institutes (Fig.21).

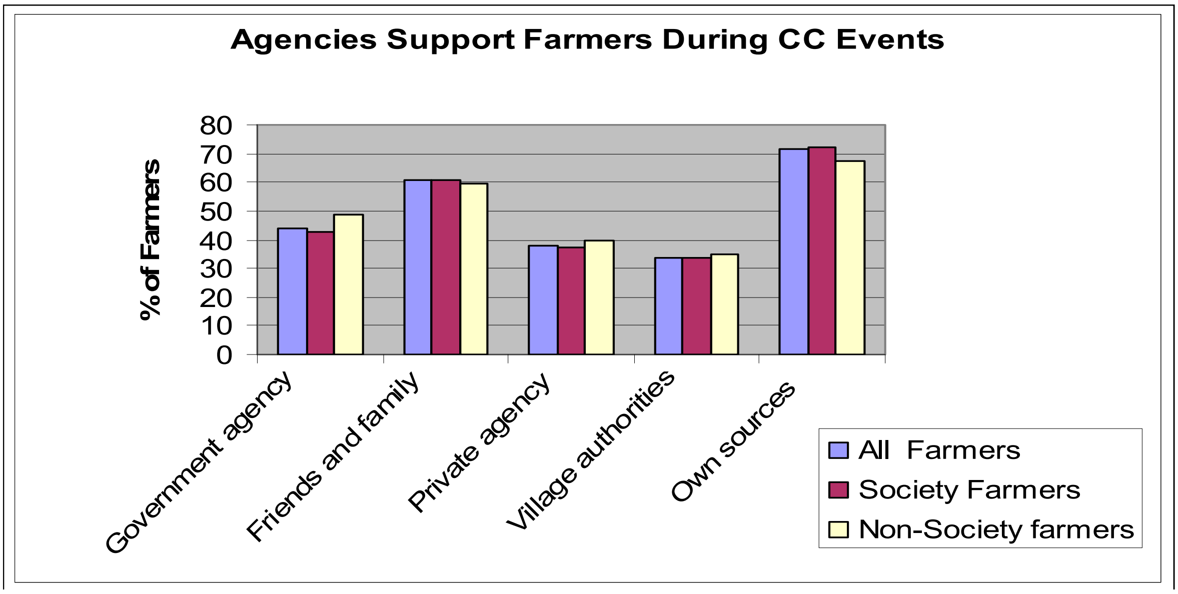

Fig.21. Agencies that support framers to overcome climate change events

7.2 Recommended adaptation measures for future predicted climate change events

The adaptation measures to be followed by farmer, science and technology and institutional and policy group from the outcome of stakeholder workshop are presented in ANNEXURE-IV. The summary of recommended adaptation measures that have been endorsed in stake holder panel consultation meeting are presented here.

7.2.1 Farmers' technical adaptation measures

Building farmer resilience

The farmer can implement a wide range of adaptation measures on the farm ranging from purchase and use of technology, changes in pond design to changes in production methodology and timing. However, small scale farmers do not have the financial resources to undertake many of the potential adaptation measures.

Therefore it is important to assist the farmers now to become more profitable so that they can cope with the stronger and more unpredictable weather conditions and afford make the recommended adaption measures.

Improving profitability

Profitability can only be increased by a reduction in operating costs, increase in productivity or an increase in market price of shrimp or raising higher value species. Stable market prices can be achieved by encouraging processors to locate close by and for the farmers to agree yearly contract price to supply the processors. There needs to be a systematic techno-economic study undertaken to analyse the most cost effective solution for the farmers to improve their profitability

Resist climate change or accept climate change?

The farmer needs to make a decision to resist climate change or to accept climate change and find ways to live with the consequences. For example, increased rainfall intensity together with increasing sea level rise is leading to increased frequency and higher floods. To resist this impact the farmer can resist flooding by strengthening and increasing the height of the individual ponds dykes and farm bunds. To live with flooding, the farmer can purchase nets that are deployed on the top of the dykes so that when a flood occurs, the shrimps remain in the ponds.

Recommendations for technical adaptation measures

Farmers recommendation 1: Strengthening and increasing the height of pond dykes and farm bunds

Many small–scale farmers do not have farm bunds owing to the smaller size of farms and in many cases the height of bund is not sufficient to avoid the damage to infrastructure in the farms during intense cyclones/storm surges and sea level rise. Pond dykes in general are to be strengthened every year due to the action of water currents in the pond leading to erosion of soil.

It is necessary to strengthen the individual pond dykes especially in the areas prone to cyclones and flood to prevent the escape of shrimp. Netting around the pond, strengthening the bund with sand bags are of low investment and permanent solution for bund with HDP polythene lining is of high investment adaptation measure. The farmers can undertake this work by themselves but they should be provided with easy access to soft loans or preferably incentives made available for increasing the height of farm bunds and especially for renovating work after the damage due to the extreme climatic events. The calamity relief compensation fund should be made available to attend the renovation works.

Farmers recommendation 2: Implementation of better management practices (BMPs) related with climate change adaptation measures

Water quality in culture ponds changes due to seasonal variations and sudden shifts in weather parameters viz., heavy rains, high temperature resulting in flood and drought. Feed intake by animals will decrease during high temperature and on cloudy days. In these situations, farmers have to implement BMPs recommended to maintain water quality and shrimp heath. The farmers in most of the time are in breakeven situation and are not in a position to invest on adaptation measures to cope with the changes in climate.

Due to seasonal variations in weather parameters, regular water quality and shrimp health monitoring helps to maintain the optimum parameters in the pond environment, optimum feed management protocols helps to avoid wastage of feed and reduce the production cost. All the BMP technologies such as use of disease free quality seed, organic juices, information on right choice of chemicals and bio-security protocols like farm fencing should be made available to farmers in improving the profits which in turn increase the capacity of farmers for further investments in climate change adaptation measures. Scientific institutions are required to give the guidelines to farmers on BMPs and Department of Fisheries (DoF), Marine Products Export Development Authority (MPEDA) and National Center for Sustainable Aquaculture (NaCSA) should make all the other logistics to implement the adaptation measures.

Farmers recommendation 3: Use of electricity for water pumping and providing aeration during weather disturbance situations

Farmers need to pump water regularly during high temperature for maintaining the water levels and operate aerators during cloudy days. As many farms are not electrified, expenditure and energy consumption with the use of diesel are high.

Replacing the diesel with electricity will help the farmers to decrease the cost of production and increases the technical and economic efficiency of farmers. It also helps in decreasing the contribution of shrimp aquaculture towards global warming potential (reducing carbon foot print). Government should take initiative to install electricity supply lines and ensure the continuous supply of electricity at lower tariff.

Farmers recommendation 4: Maintenance of buffer zone between the farms and water source for protection to farms against cyclones and storm surges

Mangroves aforestation in the buffer zone helps in giving protection to the farms from flood and other extreme weather events. Availability of land and actual implementation is a problem with respect to the plantation in the buffer zones. Most of the smaller farms cannot afford to spare their land for buffer zone.

Government should spare the land and encourage the farmers in group to cooperate each other in planting mangroves in the buffer zone between farms and source water.

Farmers recommendation 5: Collective planning by the farmers group to mitigate the impacts of climate change

Collective cooperation and planning is required among the farmers to ensure sustainable shrimp farming and to cope with climate change impacts. As a member of society / association participation in crop calendar meetings and sharing the information on the incidence of disease helps the farmer to protect the crop from diseases and to ensure good profits.

Crop calendar meetings to discuss the crop planning in advance based on the weather forecast, desilting the source water bodies for improving the quantity and quality of water, common reservoir and discharge water treatment systems and leaving the space for buffer zone and mangrove plantations in case of smaller farms are to be carried out by collective planning of farmers. DoF and NaCSA should help in formation of farmer's societies.

Additional support for adaptation measures.
The farmer can adapt to small changes in weather patterns and short term gradual climate change but they are not prepared for rapid changes or long term continuous climate change. The farmer needs to be assisted by scientific research and technology development to find solutions that will allow them to adapt to the predicted future climate change as well as developing standardised methodology for assessing socio-economic vulnerability of communities and culture systems and developing adaptation measures.

7.2.2 Science and technology adaptation measures

The farmer can adapt to small changes in weather patterns and short term gradual climate change but they are not prepared for rapid changes or long term continuous climate change. The farmer needs to be assisted by scientific research and technology development to find solutions that will allow them to adapt to the predicted future climate change.

There is a need for scientific research to understand the underlying biological processes that are affecting productivity changes due to climate change and develop potential solutions for the farmer. In addition, there is a need for scientific research to better understand climate change and its potential impacts to support the decision making by central, regional and local governments.

The new adaptation technologies will need to be cost effective, environmentally sustainable, culturally compatible and socially acceptable. The technologies will also need to be implemented which will require widespread technology transfer supported by effective institutions, formal and informal. Funding will need to be identified to pay for the necessary research and technology development.

The role of science and technology
Scientific research and technology development can play a strong role to support farmers in developing new adaptation measures to predicted future climate change as well as developing standardised methodology for assessing socio-economic vulnerability of communities and culture systems and developing adaptation measures.

Science and technology solutions
Even if new technologies are devised, and are suitable for local conditions, it can be difficult for the poorer farmers to adopt them. With small farm sizes and limited access to credit, they may have neither the ability nor the inclination to invest in new technology.

Whatever the envisaged levels of technology, it is clear that there is a need to devise national strategy for adaptation, assessing the communities and the locations at greatest risk and planning appropriately. The scientific predictions and warnings may not yet provide the level of precision desired by many planners, but they portray with certainty a rapidly warming world with consequences that globally, and for most sectors, are largely negative. A new climate is on the way. Adaptation is not a choice, it is a necessity

Technologies for adaptation
Many of these technologies are already available and widely used and it should be possible to adapt to some extent by modifying or extending existing technologies. These measures are mainly refinement of the existing or innovation of new technologies to adapt the shrimp farming to the forthcoming climate change events. The important measures are improvement of BMPs, identification of alternate species and development of technology, scientific principles in planning mitigation measures such as mangrove plantations, de-silting and deepening of drains, and construction of flood walls.

Recommendations for S &T adaptation measures

S &T recommendation 1: Increased accuracy in predictions of weather parameters and extreme climatic events and developing guidelines for the assessment of likely damage

Present predictions on weather parameters are average monthly values and available for larger geographical areas. There are no proper guidelines for the assessment of damage with respect to the infrastructure and standing crop during extreme climatic events and this information will be useful to link with the weather data generated from IMD at district level and to give agro-advisory services to the farmers.

- The predictions on temperature and precipitation have to address the seasonal shifts and sudden changes and to be downscaled to district and lower administration unit levels.
- Developing guidelines for the assessment of likely damage due to extreme climatic events

S &T recommendation 2: Predictions on water availability in both fresh and brackishwater bodies and changes in salinity regimes

It is predicted that changes in availability and quality of source water including the salinity profile in relation to weather parameters will affect shrimp production.

- The predictions on source water quantity and quality in advance will help the planners and farmers to plan the mitigation measures.

S &T recommendation 3: Identifying vulnerable coastlines and selection of suitable mangroves species and defense structures as bio-shields and barriers

It is essential to identify the vulnerable coast lines for aquaculture for planning mitigation measures. There are instances of degeneration of mangroves on river banks and coastal areas due to wrong choice of mangrove species. A variety of defense structures are available in protecting the tidal waves. Therefore there is a need for research to identify the correct species for planting and defense structure to give coastal protection against cyclones/storm surges and sea level rise.

- Undertake GIS analysis of storm surge vulnerability along the coast to identify vulnerable coastlines and most suitable areas for mangrove planting.
- Research on vulnerability, bathymetry and topography slope analysis, fetch and wind /wave analysis and identification of most suitable areas for mangrove planting.
- Research Institutes with the help of MSSRF has to identify the suitable mangrove species in the buffer zone between the shrimp farms and on the river beds along the coast.
- Proper designing of defense structures has to be done with the help of Engineering Departments in reputed Institutes.

S &T recommendation 4: Identifying species which can tolerate abiotic stress such as salinity and temperature variation as a measure of contingency planning
It is predicted that pond water temperatures will be even higher and the salinity of water will fluctuate more widely. Larger saline areas are expected to increase under CC scenarios. Studies by CIBA indicated that land shaping after Aila cyclone in West Bengal provided livelihood to the agriculture farmers whose lands became saline. The shrimp species Litopenaeus vannamei is already being cultured in low saline waters to hyper saline waters, though the growth will be poor at both the extremes. Fresh water species like IMCs are being cultured under low salinities. Paddy cum fish culture has to be encouraged in line with predicted climate change.

- Saline toleant paddy varieties suitable for integration with aquaculture species need to be investigated.
- In cyclone affected areas, the tidal inundated sites cannot be used for agriculture and the culture of brackishwater species by land shaping has to be explored.
- Specific culture technologies such as diversification of suitable economic and viable species under different climatic regimes have to be developed.
- Crop calendar activities should be provided to Government for the adaptation by the farmers.

S &T recommendation 5: Observations on the seasonal crop pattern, animal behaviour, pond dynamics and ecosystem environment in relation to climate change and extreme climatic events.

It is predicted that seasonal variations with high temperatures and rainfall will affect the productivity of ponds and changes in water quality through the variations in salinity, pH and oxygen levels. High temperatures also prolongs the crop duration due to low feed intake and poor growth. The source waters quality also affected due to the seasonal variations and it is necessary to understand the basic principles underlying these aspects. Research Institutes with the help of SAUs and DoF has to undertake research on the following aspects in relation to climate change:

- Physiological aspects of shrimp behaviour in terms of feeding metabolism and reproduction
- Tidal amplitude and changes in source water quantity and quality parameters, pond water parameters through water quality monitoring in selected areas to identify the seasonal variation and to correlate with the changes in weather parameters.

- Pond dynamics and productivity including plankton diversity
- Impact of high temperature and rainfall on shrimp productivity

S &T recommendation 6: Weather anomalies that trigger disease incidence and the impact of changing seasonal patterns on emergence of new diseases has to be investigated

A rapid change in water quality parameters and weather parameters variation leads to a higher incidence of disease. Hence, disease occurrence pattern in relation to changing weather conditions has to be studied in understanding the prevalence of existing diseases and incidence of new emerging diseases.

- Epidemological investigations in understanding the relationship between weather disturbances and diseases incidence.
- Research Institutes in association with other organizations should arrange regular monitoring of pathogens and shrimp disease outbreaks and provide recommendations on treatment to the farmers.

S &T recommendation 7: Research interventions on better management practices (BMPs) in the context of climate change

BMPs are being implemented by many farmers though their scientific principles were not understood. Hence it is required to test the effectiveness of BMPs in the context of climate change with specific reference to pond design to withstand ECEs, changes in water quality and increased disease incidence due to weather disturbances for popularizing them as adaptive measures among the farmers. Research Institutes in association with NaCSA and fisheries colleges can undertake these studies on the following areas:

- Standardisation of feeding and fertiliser management and liming protocols
- Maintenance of water level and topping -up
- Oxygen enhancers
- Width of the bund and engineering structures for strengthening the farm peripheral dykes
- Reservoir maintenance and water treatment and mesh size to be used for water filtration

S &T recommendation 8: Actual aeration requirements estimation and improving the efficiency of pumping and aeration

Water pumping is required to exchange water for maintaining water quality parameters in optimum range and to top-up the water to maintain the water level. The necessity of pumping is more under high temperature situations. Similarly aeration requirement is high during cloudy days and heavy rainfall conditions. Studies by CIBA indicated that farmers are using more aeration than the actual requirement. The energy consumption for the operation of motor pumps and aerators is high and if are not made efficient, it will further increase the energy requirement.

- It is necessary to estimate the actual aeration requirement to avoid the use of excess aerators.
- The efficiency of aerators and pumps can be improved with mechanical interventions by Aquaculture Engineering Departments. This will help in reducing the production cost for farmers and also in decreasing the carbon foot print from shrimp aquaculture.

S &T recommendation 9: Development of low fish meal feed technology using plant protein sources

In the predicted scenario of limited availability of fish meal and fish oil, alternative protein sources are to be explored for immediate requirement of feed manufacturing industry to reduce the cost of feed.

- Research efforts need to be intensified to develop low fish meal feed technology using plan protein sources and popularization of this feed technology among the farming communities

S &T recommendation 10: Awareness materials on climate change impacts and adaptation measures and studies on climate field school concept

There is a lack of awareness and understanding on climate change by shrimp farmers particularly of predicted future climate change and potential adaptation measures.

- Research Institutes with the help of other organizations should collect science based resource materials and then prepare training materials on present and future predicted climate change, potential adaptation and mitigation measures for aquaculture.
- The training materials should be preferably translated into vernacular languages and made available to all stakeholders. The training materials should be updated regularly as climate science research and lessons learned from adaptation measures developed elsewhere is developing rapidly.
- The training programs can be arranged by Research Institutes to trainers/technicians who in turn will train the farmers (actual operators and care takers).
- The Climate Field School concept being followed in other countries can be replicated and based on the feedback improvements have to be suggested.

7.2.3 Policy and Institutional adaptation measures

Policy recommendation 1: Licensing of aqua farms so that shrimp farmers can get access to institutional credit support and crop insurance and to recognize aquaculture on par with agriculture to get electricity at low tariff.

Many aqua farmers do not have license and therefore are not in a position to get the institutional loans, crop insurance and other Govt. incentives. The electricity charges were high for aquaculture compared to agriculture and many farms are not still electrified. The insurance provided to aqua farmers is at high premium unlike agriculture.

Reclassification of coastal lands where agriculture is not suitable for aquaculture purpose and certifying the individual farmers by the State Revenue Department is of immediate requirement to get license to aqua farms from Coastal Aquaculture Authority (CAA). The license will help to get the calamity relief, soft loans and other subsidies incentives provided by the Government. Farmer's friendly insurance to aquaculture with low premium has to be in place to compensate the damage to the farm infrastructure and loss of stock caused by extreme weather events and subsequent diseases. State Department of Fisheries together with the insurance companies and commercial banks should jointly develop measures to help shrimp farmers. Commercial and Government banks should provide soft loans to aquaculture on par with agriculture. Small-scale shrimp farmers should be provided with electricity at low tariff on par with agriculture by the State Electricity Department. This will help to reduce the cost of production by minimising the dependency on diesel, which in turn also reduces carbon foot print.

Policy recommendation 2: To secure National Calamity Contingency Fund (NCCF) for shrimp farmers to compensate the losses due to extreme weather events.

In the existing calamity relief proforma of Ministry of Home Affairs, Govt. of India, shrimp farming is not mentioned separately and equated with fish ponds. Whenever extreme weather event occurs, a Central team consisting of members (Ministry of Agriculture and Ministry of Animal Husbandry &

Fisheries) nominated by the Government visit the affected areas and make damage assessment of different sectors.

The policy change should include relief compensation to shrimp farmers and list it in the calamity relief proforma. During extreme climatic events, in the damage assessments by Central team, shrimp aquaculture was so far never considered and Government should also consider this sector in the near future.

Policy recommendation 3: To improve early warning systems on cyclones and floods.

Cyclone and flood are the two critical climatic events perceived as threats to the shrimp farming and there is a need to provide advanced warnings to farmers for helping them to prepare in advance and reduce losses. Although weather forecasting is already in place, currently, the farmers do not get timely information.

The Indian Meteorological Department (IMD) and the Central Water Commission (CWC) should provide a micro-level (district level) forecast on cyclones/storm surges and floods respectively. Application of ICT-SMS through mobile phones to give early warnings on cyclone and flood from the identified service providers can be experimented on pilot scale by IMD. This will help the farmers to implement the preparedness measures and minimize losses from the extreme weather events.

Policy recommendation 4: To develop contingency plans to overcome losses from extreme weather events or changes in climate affecting the normal crop calendar.

Alternative crops /species should be made available in case of shrimp crop failure due to extreme weather events or changes in climate due to heavy rains or high temperatures. Culturing finfish reduces the risks and vulnerability by withstanding the variations in water quality parameters due to climatic events and can be cultured throughout the year.

Finfish broodstock facilities have to be established for quality seed production in the shrimp growing areas and, efforts have to be made for the supply of finfish seeds to the farmers.

Policy recommendation 5: Climate resilient structures to withstand extreme climatic events - Repair of flood bunds and improve the quality and availability of source waters through dredging and deepening of water bodies

The bunds in preventing the floods will help the farmers in minimizing the losses. Quality and availability of water will be a problem in source waters for shrimp farming due to extreme changes in weather parameters such as high temperatures and heavy rainfall. Due to limited availability of water, conflicts arise among the stake holders depending on the same water source.

The flood bunds have to be constructed in the flood prone hazard areas and already existing bunds have to be monitored every year for the repair work. Public Works Department (PWD) of respective States has to monitor this work. In general structures constructed by PWD, where water flow is regulated, they have to be taken care in not inducing extreme flooding. Irrigation and Drainage Department has to carry the dredging and deepening of water bodies to improve the availability and quality of source waters. District level planning for water budgeting is required to avoid the conflicts between aquaculture and agriculture. As there is no special policy on supplying freshwater to aquaculture, at least in the lean seasons of agriculture, water should be diverted exclusively for aquaculture.

Policy recommendation 6: To strengthen coastal systems against storm surge and sea level rise by planting tree barriers

Mangroves are effective in protecting the shrimp farms and coastal villages from extreme climatic events. Casuarina tree plantations on some parts of the east coast have proved to be effective barriers against storms and floods.

Aforestation programmes have to carried out by the Forest Department to strengthen coastal ecosystem and acts as shelter belt against storm surge and sea level rise. Restrictions on mangrove plantation outside the reserve forest area have to be liberalized for development of community based mangroves in integration with aquaculture.

Policy recommendation 7: To build capacity of farmers through trainings and initiation of Climate field school

Farmers need to be trained on farm management measures to be followed during extreme weather events including the better management practices. Since majority of the farmers were of a relatively low literacy background, the capacity building programmes need to be on 'learning by doing mode' and should be in local language. Pictorial guides and posters would enhance their understanding.

Research Institutes have to give training to trainers from Department of Fisheries and National Centre for Suatainable Aquaculture (NaCSA) and these trainers can coordinate the short/long term training programmes to farmers (caretakers and operators). These training programs have to be operated in each mandal (administrative unit of district) to cover large number of farmers. National Fisheries Development Board (NFDB) can provide the funding support to the training programmes. Fishery extension officers in sufficient number are required in the Department of Fisheries to provide services to farmers. Climate field school concept has to be initiated based on the successful model being operated in Philippines either by NaCSA for aquaculture or by Govt. for both agriculture and aquaculture.

Policy recommendation 8: Encouraging women's participation in future climate change adaptation measures

Women's participation is already seen in day to day farming activities starting from the stocking to harvesting and is equally vulnerable to climate change events either directly or indirectly. In case of extreme climatic events, loss to the crop and infrastructure in the farms affect both the genders equally. Hence, addressing gender issues with suitable strategies or programmes is important in improving their adaptive capacity.

It is recommended that women's role should be increased, especially in implementing the adaptation measures. It is required that in all trainings undertaken by any department, participation of women should be encouraged.

8. Policy options, Institutions and framework

The scale of CC impacts and policy frame work for the adaptation measures is shown in the framework given below.

Scales

	Climate change		Impacts	
Ocean	Sea level rise		More BW area	Salinization-FW bodies
Catchment area/Source water body (Creek, River, Agricultural drains, Back waters)	Precipitation (shift/ volume/	Temperature (increase/ shift/ sudden change)	Changes in water quality (salinity, pH and nutrients)	
Farm clusters			Flooding/ reduced water availability	
Farm			Changes in salinity, pH, dissolved oxygen, disease incidence	

Adaptation measures

	Who	What
Mandal/Taluk	NaCSA	Training, crop planning
District	Fisheries department	Aquaculture planning Training Licence to aqua farms
	PWD and Irrigation & Drainage Department	Climate resilient structures
State	Department of Fisheries	Insurance policy
National	Ministry of Agriculture and Ministry of Animal Husbandry & Fisheries IMD and CWC	Assessment of damage due to ECEs, Quarantine risk assessment of new species
	National Disaster Management Authority - Ministry of Home Affairs	Early warning systems National Calamity Contingency Fund (NCCF)
	NFDB	Funding for capacity building

9. Conclusion

Small-scale shrimp aqua farmers are already experiencing the effects of climate change such as increased frequency and strength of floods and cyclones, high temperature and increased and unpredictable rainfall. Sustaining tiger shrimp production is crucial for the large number of farmers who are dependent on it for their livelihoods. The use of participatory processes such as facilitated semi-structured focus group discussion and stakeholder workshop, a novel technique for the shrimp farmers and stakeholders and interviewing 300 farmers through structured questionnaire helped in understanding the perceptions, vulnerability, and adaptability to climate change on small scale shrimp farmers and developing the farmers', scientific and policy adaptation measures, and the time line and organizations responsible for the implementation. They have low capability to cope with these changes or to implement adaptation measures. Though farmers have started to adapt to the extreme weather events, their socio-economic context makes them vulnerable to climate variability. To reduce their vulnerability, first there is a need to increase profitability which would then allow them to make the necessary adaptation measures to cope with the predicted climate change. They also need support from scientific, research and technological development to find solutions as well as larger scale adaptation measures to be implemented by State Government.

Research on accuracy predictions of weather parameters and water availability in source waters, identification of vulnerable coastal areas and mangroves species, and identification of species for contingency planning will help in planning the mitigation measures in advance. Those farmers who had successfully overcome the negative effect of cyclone storm and floods have increased their efficiency levels. Studies on shrimp physiology and metabolism in relation to changes in weather parameters, better management practices in relation to climate change, improving the pumping and aeration efficiency, epidemiological investigations on emergence of new diseases, location specific culture technologies under different climatic regimes low fish meal feed technology using plant protein sources will lead to solutions in framing adaptation measures. Training curriculums and materials development and facilitating training and capacity building helps to reduce the shrimp farmer's vulnerability and improves the adaptation capacity.

Some of the guidelines suggested for future policies do not require major changes and can provide good support to farmers to adapt to changing climate. Issuing license to farmers, providing electricity on par with agriculture, crop insurance at low premium, calamity relief and contingency planning for farmers against climate risks, and better land use planning will enable the farmer more resilient to cope with the extreme climatic events. Strengthening coastal defense systems against sea-level rise, cyclones/storm surge and floods, improving forecasting systems and more coordinated action at the State and Central level will help in planning mitigation measures. Training and capacity building of both the genders helps to reduce their vulnerability and improves the adaptive capacity.

Improving and applying knowledge on the constraints and opportunities for enhancing adaptive capacity is necessary to reduce vulnerabilities associated with climate change. The farmer can adapt to small changes in weather patterns and short term gradual climate change but they are not prepared for rapid changes or long term continuous climate change. The farmer needs to be assisted by scientific research and technology development to find solutions that will allow them to adapt to the predicted future climate change. A very strong focus on building general adaptive capacity can help the poor shrimp aquaculture communities to cope with new challenges. The farmers should have a commitment to implement the adaptive measures at the farm level (better management practices) and all the Govt. Departments, research organizations and NGOs have to help them in increasing their adaptive capacity. Both Central and State Govt. should make strong policies on climate change with a focus to increase the adaptation capacity of all the stakeholders involved in the shrimp farming sector. Integration of climate change considerations into the policies in aquaculture sector can facilitate adaptation and ensure that they contribute to adaptive capacity from national to local levels.

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ANNEXURE -1

Climate normals in Krishna District (Climatological table period: 1951-1980)

Month	Mean Temperature (°C)		Mean Total Rainfall (mm)	Mean Number of Rainy Days	Mean Number of days with			
	Daily Minimum	Daily Maximum			Hail	Thunder	Fog	Squall
Jan	18.7	30	0.9	0.1	0	0	2	0
Feb	20.1	32.7	5.3	0.4	0	0.4	2.3	0
Mar	22.4	35.4	9.6	0.5	0	0.9	2.1	0
Apr	25.5	37.4	14.3	1	0	2.9	0.2	0
May	27.5	39.8	51.3	3.1	0	6.2	0	0.1
Jun	27	37.2	131.9	7.6	0	7.1	0	0
Jul	25.4	33.2	218.4	12.6	0	4.7	0	0.1
Aug	25.1	32.4	185.6	11.5	0	4.9	0	0
Sep	25.1	32.6	163.5	8.8	0	8.2	0.2	0
Oct	24	31.8	142.6	7.1	0	7.6	0.3	0
Nov	21.3	30.7	51.3	2.8	0	1.6	0.1	0
Dec	19.1	29.6	6.7	0.6	0	0	0.6	0
Annual	23.4	33.6	998.2	56.1	0	44.5	7.8	0.2

Source: IMD, Vijayawada

ANNEXURE - II

Stakeholder characteristics and classification (Ranks: Very low, low, moderate, high, very high)

Stakeholders		**Stakeholder characteristics**									
Stakeholder name	**Organization**	**Stakeholder type (Beneficiaries/ Implementers / Financing agents / Decision makers) National/ State level/ local level**	**Level of stake held in adaptation of aqua-farming to CC**	**Description of stakeholder group** **Farmers organizations/ Government agencies/ NGOs/ Research and Education institutions**	**Influence over CC adaptation**	**Interests**	**Information or knowledge about aqua-farmer CC problems**	**Problems for**	**Required actions to support aqua-farmer CC adaptation**	**Primary Activity**	**Resources at disposal for assistance of aqua-farmers adaptation to CC**
Farmers	Societies nearer to coast	Beneficiaries	Primary stakeholders	Small scale farmers, rural	**Low** influence, Not much influence on policy	**High** as livelihood are impacted	High – observed directly	Production and profitability impacted by CC; more vulnerable to ECEs.	Govt. support	Shrimp Farming	Low
Farmers	Societies in inland area	Beneficiaries	Primary stakeholders	Small scale farmers, rural	**Low** influence, Not much influence on policy	**High** as livelihood are impacted	High – observed directly	Production and profitability impacted by CC; less vulnerable to ECEs (Flooding and inundation but not drought)	Govt. support	Shrimp Farming	Low

Stakeholders		Stakeholder characteristics									
Stakeholder name	**Organization**	**Stakeholder type (Beneficiaries/ Implementers / Financing agents / Decision makers) National/ State level/ local level**	**Level of stake held in adaptation of aqua-farming to CC**	**Description of stakeholder group Farmers organizations/ Government agencies/ NGOs/ Research and Education institutions**	**Influence over CC adaptation**	**Interests**	**Information or knowledge about aqua-farmer CC problems**	**Problems for**	**Required actions to support aqua-farmer CC adaptation**	**Primary Activity**	**Resources at disposal for assistance of aqua-farmers adaptation to CC**
Joint Director of Agriculture	Department of Agriculture, Krishna District	Implementers/Local level	Secondary stakeholders	Government of Andhra Pradesh	Moderate influence on policy	Moderate as end users, farmers are affected	Not much. But have more knowledge in agriculture	Motivating farmers to implement adaptation measures	Adaptation and policy measures to be implemented	Extension, Assessment of extreme climatic events impact on agriculture, Implementation of Govt. schemes and relief measures,	Not for aquaculture, but for agriculture farmers. The knowledge can be shared.
CEO/Regional Coordinator /Field manager NaCSA	National Centre for Sustainable Aquaculture	Implementers /Local level Working in the field with farmers	Secondary stakeholders	Government	Moderate influence on policy	Moderate as end users, farmers are affected	Moderate – Observed indirectly	Motivating farmers to implement BMPs and also to implement any CC adaptation,	Policy measures to be implemented	Extension and mobilisation of small scale farmers	Moderate

Stakeholders		Stakeholder characteristics									
Stakeholder name	**Organization**	**Stakeholder type (Beneficiaries/ Implementers / Financing agents / Decision makers) National/ State level/ local level**	**Level of stake held in adaptation of aqua-farming to CC**	**Description of stakeholder group Farmers organizations/ Government agencies/ NGOs/ Research and Education institutions**	**Influence over CC adaptation**	**Interests**	**Information or knowledge about aqua-farmer CC problems**	**Problems for**	**Required actions to support aqua-farmer CC adaptation**	**Primary Activity**	**Resources at disposal for assistance of aqua-farmers adaptation to CC**
Deputy Director (Aqua) MPEDA	Marine Products Export Development Authority	Implementers / Local level	Secondary stakeholders	Government	Moderate influence on policy	Moderate as end users, farmers are affected	Moderate – Observed indirectly	Motivating farmers to continue the culture	Schemes to be formulated for implementation	Promotion and development through scheme s	Moderate
Deputy Director, Assistant Directors and FDOs	AP State Fisheries Department	Implementers / Local (District) Level	Secondary stakeholders	Government	Moderate influence on policy	Moderate as end users, farmers are affected	Moderate – Observed indirectly	Preparedness and Damage assessment in case of ECEs and motivating farmers to continue the culture	Actual assessment of damage in case of ECEs and implementation of measures	Extension activities, capacity building, vulnerability and damage assessment	Moderate
Secretary/ Director (Tech.) – CAA	Coastal Aquaculture Authority	Decision makers/National level	Secondary stakeholders	Government	**High** influence on policy	Moderate as end users, farmers are affected	Moderate – Observed indirectly	Deciding policy measures	Policies to be formulated	Regulation of aquaculture, Licensing and policies formulation	High

Stakeholders		Stakeholder characteristics									
Stakeholder name	**Organization**	**Stakeholder type (Beneficiaries/ Implementers / Financing agents / Decision makers) National/ State level/ local level**	**Level of stake held in adaptation of aqua-farming to CC**	**Description of stakeholder group** **Farmers organizations/ Government agencies/ NGOs/ Research and Education institutions**	**Influence over CC adaptation**	**Interests**	**Information or knowledge about aqua-farmer CC problems**	**Problems for**	**Required actions to support aqua-farmer CC adaptation**	**Primary Activity**	**Resources at disposal for assistance of aqua-farmers adaptation to CC**
Chairman/ Directors - NFDB	National Fisheries Development Board	Decision makers/ National level	Secondary stakeholders	Government	**High** influence on policy	Moderate as end users, farmers are affected	Moderate – Observed indirectly in farms	Deciding policy measures and schemes for adaptation solutions	Policies and supporting schemes to be formulated	Capacity building, training, Increase the productivity of fisheries and aquaculture	Very High
Officer-in charges of	District level Disaster	Implementers/ Local level	Secondary stakeholde	Government	Moderate influence on	Moderate as end	High – Observed	Damage assessment in	Actual assessment	Preparedness,	Moderate
Departments such as Fisheries/ Agriculture /Revenue etc.	Management Committee		Secondary stakeholders		policy	users, farmers are affected	indirectly in case of ECEs	case of ECEs	of damage in case of ECEs and implementation of measures	and mitigation measures and damage assessment due to ECEs	

Stakeholders		Stakeholder characteristics									
Stakeholder name	**Organization**	**Stakeholder type (Beneficiaries/ Implementers / Financing agents / Decision makers) National/ State level/ local level**	**Level of stake held in adaptation of aqua-farming to CC**	**Description of stakeholder group** **Farmers organizations/ Government agencies/ NGOs/ Research and Education institutions**	**Influence over CC adaptation**	**Interests**	**Information or knowledge about aqua-farmer CC problems**	**Problems for**	**Required actions to support aqua-farmer CC adaptation**	**Primary Activity**	**Resources at disposal for assistance of aqua-farmers adaptation to CC**
In-charge Observatory	Indian Meteorological Department	Data source/ Local Level	Secondary stakeholders	Government	Moderate influence on policy	**Low** interest as not involved directly	High on CC but low related to aqua farmers	Accurate forecast and advise to aqua farmers	Reliable and advanced forecast	Forecasting of cyclones / storms and daily meteorological data	Low
Officer-in-charge of District	Central Water Commission	Data source/ Local level	Secondary stakeholders	Government	Moderate influence on policy	**Low** interest as not involved directly	High on CC but low related to aqua farmers	Accurate forecast and advise to aqua farmers	Reliable and advanced forecast	Forecasting of floods	Low

Stakeholders		Stakeholder characteristics									
Stakeholder name	**Organization**	**Stakeholder type (Beneficiaries/ Implementers / Financing agents / Decision makers) National/ State level/ local level**	**Level of stake held in adaptation of aqua-farming to CC**	**Description of stakeholder group Farmers organizations/ Government agencies/ NGOs/ Research and Education institutions**	**Influence over CC adaptation**	**Interests**	**Information or knowledge about aqua-farmer CC problems**	**Problems for**	**Required actions to support aqua-farmer CC adaptation**	**Primary Activity**	**Resources at disposal for assistance of aqua-farmers adaptation to CC**
Scientists	Central Institute of Brackishwater Aquaculture	Researchers/Natio Nal	Secondary stakeholders	Government - Research Institution	Moderate influence on policy	Moderate as end users, farmers are affected	High on CC from literature and moderate related to aqua farmers	Understanding CC problems and development of mitigation and adaptation strategies	Research for adaptive solutions and methodology for damage assessment in case of ECEs	Projects on climate change, Research on development of adaptiv e measures	Low
Scientists	National Institute of Hydrology – Kakinada Centre	Researchers/ National	Secondary stakeholders	Government - Research Institution	Moderate influence on policy	Moderate as end users, farmers are affected	High on CC but low related to aqua farmers	Understanding CC problems and development of mitigation and adaptation strategies	Research for adaptive solutions	Research on development of adaptiv e measures	Low
Scientists	Central Institute of Freshwater Aquaculture – Regional Centre, Vijayawada	Researchers/ National	Secondary stakeholders	Government - Research Institution	Moderate influence on policy	Moderate as end users, farmers are affected	High on CC from literature and moderate related to aqua farmers	Understanding CC problems and development of mitigation and adaptation strategies	Research for adaptive solutions	Research on development of adaptiv e measures	Low

Stakeholders		Stakeholder characteristics									
Stakeholder name	**Organization**	**Stakeholder type (Beneficiaries/ Implementers / Financing agents / Decision makers) National/ State level/ local level**	**Level of stake held in adaptation of aqua-farming to CC**	**Description of stakeholder group** **Farmers organizations/ Government agencies/ NGOs/ Research and Education institutions**	**Influence over CC adaptation**	**Interests**	**Information or knowledge about aqua-farmer CC problems**	**Problems for**	**Required actions to support aqua-farmer CC adaptation**	**Primary Activity**	**Resources at disposal for assistance of aqua-farmers adaptation to CC**
Scientists/ Training Organisers	KVK-ANGARU & Undi Research Station	Researchers/ Trainers - National level	Secondary stakeholders	Government - Research and Extension Institute	Moderate influence on policy	Moderate as end users, farmers are affected	High on CC from literature and moderate related to aqua farmers	Understanding CC problems and development of mitigation and adaptation strategies	Research for adaptive solutions and training the farmers	Extension and Training	Low
Trainers/ Scientists	State Institute of Fishery Technology – AP State Fisheries	Researchers/ Trainers - state level	Secondary stakeholders	Government - Research and Extension Institute	Moderate influence on policy	Moderate as end users, farmers are affected	High on CC from literature and moderate related to aqua farmers	Understanding CC problems and development of mitigation and adaptation strategies	Research for adaptive solutions and training the farmers	Extension and Training	Low
Feed manufacturer	CP Feed, Chennai	Beneficiaries	Secondary stakeholder	Private manufacturer	**Low** influence on policy	High as production is affected by supply of fish meal (FM)	Low	Quality production of feed	Supply of quality feed	Manufacturing of feed	Low
Feed manufacturer	The Waterbase Ltd, Nellore	Beneficiaries	Secondary stakeholder	Private manufacturer	Low influence on policy	High as production is affected by FM s	Low	Quality production of feed	Supply of quality feed	Manufacturing of feed	Low

Stakeholders		Stakeholder characteristics									
Stakeholder name	**Organization**	**Stakeholder type (Beneficiaries/ Implementers / Financing agents / Decision makers) National/ State level/ local level**	**Level of stake held in adaptation of aqua-farming to CC**	**Description of stakeholder group** **Farmers organizations/ Government agencies/ NGOs/ Research and Education institutions**	**Influence over CC adaptation**	**Interests**	**Information or knowledge about aqua-farmer CC problems**	**Problems for**	**Required actions to support aqua-farmer CC adaptation**	**Primary Activity**	**Resources at disposal for assistance of aqua-farmers adaptation to CC**
Feed manufacturer	East Coast Aqua feeds	Beneficiaries	Secondary stakeholder	Private manufacturer	Low influence on policy	High as production is affected by supply of fish meal	Low	Quality production of feed	Supply of quality feed	Manufacturing of feed	Low
Input dealer	Feed dealer	Beneficiaries	Secondary stakeholders	Private dealer	Low influence on policy	Moderate as end users, farmers are affected	Low	Decrease in the sale of products	Supply on credit basis	supply of feed	Low
Processors	Processing plants	Beneficiaries	Secondary stakeholder	Private	Low influence on policy	Moderate as farmers are affected	Low	Decrease in the supply for processing	Offering good price to farmers	Processing of harvested produce	Low

Stakeholders		Stakeholder characteristics									
Stakeholder name	**Organization**	**Stakeholder type (Beneficiaries/ Implementers / Financing agents / Decision makers) National/ State level/ local level**	**Level of stake held in adaptation of aqua-farming to CC**	**Description of stakeholder group Farmers organizations/ Government agencies/ NGOs/ Research and Education institutions**	**Influence over CC adaptation**	**Interests**	**Information or knowledge about aqua-farmer CC problems**	**Problems for**	**Required actions to support aqua-farmer CC adaptation**	**Primary Activity**	**Resources at disposal for assistance of aqua-farmers adaptation to CC**
Technicians	Aqua and PCR labs	Beneficiaries	Secondary stakeholder	Private	Low influence on policy	Moderate as end users, farmers are affected	Low	Decrease in the no. of samples and thus livelihood	Economical testing rates	Analysis services such as PCR seed testing and soil and water quality testing	Low
Hatcheries	All India Shrimp Hatcheries Association (AISHA)	Beneficiaries	Secondary stakeholder	Private	Low influence on policy	High due to erratic supply of brood stock	Moderate – observed indirectly	Quality seed production	Good quality seed	Production and supply of seed	Low
Brood stock suppliers	Fishermen	Beneficiaries	Secondary stakeholder	Private	Low influence on policy	High as livelihoods are impacted directly	Moderate – observed indirectly	Quality brood stock supply	Good quality broodstock	Collection of brood stock	Low

Stakeholders		Stakeholder characteristics									
Stakeholder name	**Organization**	**Stakeholder type (Beneficiaries/ Implementers / Financing agents / Decision makers) National/ State level/ local level**	**Level of stake held in adaptation of aqua-farming to CC**	**Description of stakeholder group** **Farmers organizations/ Government agencies/ NGOs/ Research and Education institutions**	**Influence over CC adaptation**	**Interests**	**Information or knowledge about aqua-farmer CC problems**	**Problems for**	**Required actions to support aqua-farmer CC adaptation**	**Primary Activity**	**Resources at disposal for assistance of aqua-farmers adaptation to CC**
Brood stock suppliers	Fishermen (Boat owners)	Beneficiaries	Secondary stakeholder	Private	Low influence on policy	High as livelihoods are impacted directly	Moderate – observed indirectly	Quality brood stock supply	Good quality broodstock	Hiring boats, Collection of brood stock	Low
NGO	Society of Aquaculture Professionals (SAP)	Implementers	Secondary stakeholder	NGO	Low influence on policy	Moderate as end users farmers are affected	Low	Overall improvement of the sector	Involvement in all the sectors for adaptive solutions	Development of aquaculture	Low
NGO	NGO - National Association of Fishermen (NAF)	Implementers	Secondary stakeholder	NGO	Low influence on policy	Moderate as end users fishermen are affected	Low	Alternative livelihood measures	Livelihood measures	Livelihood improvement	Moderate
Prof. / Senior lecturer	Fisheries College, Nellore	Implementers	Secondary stakeholder	Research and Education	Low influence on policy	Moderate as teaching material should include chapters on CC impacts	High on CC from literature and moderate related to aqua farmers	Understanding CC problems and development of mitigation and adaptation strategies	Research for adaptive solutions and training the farmers	Training	Low

ANNEXURE - III

Stakeholder tasks analysis

Tasks related to shrimp farming and climate change											
Stakeholder name/ Organisation / sector	**Shrimp Culture**	**Support: shrimp seeds / processing**	**Direct financial support**	**Budget allocation for projects**	**Aqua-Farmer Extension**	**Marketing**	**Aquaculture policy / management**	**Natural resource management impacting on aquaculture**	**Technical support and training**	**Research on understanding CC issues**	**Collect/ record/ disseminate weather/ climate date**
Farmers	3										
Shrimp hatchery		3									
NaCSA					3				3		
MPEDA			3 (through subsidy schemes)	3	3	3			3		
State Fisheries Department					3		3		3		
Coastal aquaculture authority							3				

Tasks related to shrimp farming and climate change											
Stakeholder name/ Organisation / sector	**Shrimp Culture**	**Support: shrimp seeds / processing**	**Direct financial support**	**Budget allocation for projects**	**Aqua-Farmer Extension**	**Marketing**	**Aquaculture policy / management**	**Natural resource management impacting on aquaculture**	**Technical support and training**	**Research on understanding CC issues**	**Collect/ record/ disseminate weather/ climate date**
National Fisheries Development Board							3				
District level Disaster Management Committee								3			
Research and Academic Institutes	3			3	3				3	3	
Indian Meteorological Department											3
Central Water Commission								3			3
Office / Department responsible for climate change								3			
Water authorities								3			
NGOs	3				3				3		

Tasks related to shrimp farming and climate change											
Stakeholder name/ Organisation / sector	**Shrimp culture**	**Support: shrimp seeds / processing**	**Direct financial support**	**Budget allocation for projects**	**Aqua-Farmer Extension**	**Marketi ng**	**Aquaculture policy / management**	**Natural resource management impacting on aquaculture**	**Technical support and training**	**Research on understanding CC issues**	**Collect/ record/ disseminate weather/ climate date**
Feed manufacturers		3									
Input dealers (Feed, Chemicals and probiotics)		3									
Broodstock suppliers (Fishermen)		3									
Farm consultants		3									
Banks			3 (through loans)								
Processors/Exporters		3				3					

ANNEXURE - IV

A. Farmer's adaptive measures

Climate change	Impacts	Measures based on priority (P)	Identified agency by the farmer (Time line within parentheses)
Seasonal Change	• Crop season delayed • Variation in salinity, pH, oxygen levels and diseases incidence • Temperature variation (slow growth and less feeding) • Brood stock collection problem	P.1 Water quality monitoring P.2 Alternative marketing strategy P.3 Alternative species culture (farmer as per need) P.4 Continuous supply of electricity P.5 Specify the good farm location	P.1 Analysis by consultant and scientists (Immediate) P.2 Govt. - MPEDA and NFDB (Immediate) P.3 R&D Institutes (Short term) P.4 Govt. (Immediate) P.5 Farmers - help from experienced consultants (Short term)
Low temperature	• Decline in oxygen level (disease) • Pathogenic attack (less feeding, survival reduced) • Poor growth moulting problem (crop reduced)	P.1 Better management practices P.2 Continuous supply of electricity	P.1 Farmer – help from scientists from research organizations and universities, feed technicians (Immediate) P.2 Govt. (Immediate)
Heavy rainfall	• Variation in salinity and oxygen levels • Disease incidence • Dyke damages (animals escape, ponds submerged, infrastructure damage) • Electricity problem • Approach to farm is difficult	P.1 Netting around the pond P.2 Strengthening the bund with sand bags P.3 Permanent solution for bund with HDP polythene lining	P.1 Farmer (Immediate) P.2 Farmer – help from Govt. (Immediate) P.3 Govt./agencies (Immediate)
High temperature	• Increase in pH (disease, moulting) and salinity (slow growth and extension of culture period • Less income • Decline in DO levels • Algal blooms development	P.1 Increase in water levels, manual de-weeding P.2 Aeration, water exchange P.3 Continuous supply of electricity	P.1 Farmer (Immediate) P.2 Farmer - advise from consultant/feed technicians (Immediate) P.3 – Govt. (Immediate)

Flooding	• Destruction of dykes • Water pollution (disease, moulting) • Production loss	P.1 Insurances, loan reschedule P.2 Harvesting of crop (solve production loss immediately) P.3 Netting around the pond P.4 Strengthening of the bunds with sand bags P.5 Proper integrated farming	P.1 Banks and Govt. (Immediate) P.2 Farmer advise from Department (Immediate) P.3 Farmer (Immediate) P.4 Farmer with the help from Govt. (Immediate) P.5 R&D Institutions and Govt. Departments
Cyclone	• Heavy rain, flood and wind (damage to life and farm infrastructure and crop loss) • High risk • Production loss		(Long term)
Low rain fall	• Increase in salinity (slow growth, culture period extended • Increase in pH (disease problem and moulting) • Less income	P.1 Reservoir maintenance and water treatment P.2 Topping-up of water and water management	P.1 Farmer (Continuous process) P.2 Farmer (Continuous process- daily)
Low tidal movement	• Effect on water exchange • Deterioration in water quality (mortality)	P.1 Reservoir maintenance and water treatment P.2 Topping-up of water and water management P.3 Deepening of drains and creeks	P.1 Farmer (Continuous process) P.2 Farmer (Continuous process- daily) P.3 Govt. (Immediate)

B. Science and technical adaptive measures

\Climate change	Impacts	Measures based on priority (P)	Responsible agency (Time line within parentheses)
Floods (due to heavy rains and cyclones)	• Destruction of dykes • Water pollution	P.1 Farm peripheral dykes (Engineering structures) P.2 De-silting the drain P.3 Width of the bund and mesh to be used for water filtration	P.1 CIBA, Aquaculture Engineering Department, IIT Kanpur (Immediate) P.2- Govt. (1-2 days before floods) Immediate P.3 NaCSA and CIBA (Immediate during crop planning pattern)
Cyclones	• Heavy rain, flood and wind • Farmers access problem • Economic loss	P.1 Farmers should follow seasonal crop pattern (Feb-June) to avoid impacts of cyclones P.2 Construction of flood banks P.3 Disseminating weather forecast P.4 Mangroves as bio-shields (identify suitable species) P.5 BMPs - Liming, oxygen enhancers, less feeding	P.1 CIBA, NaCSA, DoF (Now on regular basis) P.2 Department of Irrigation Every year (summer) mid term P.3 IMD regular basis as and when required P.4 Forest Department Immediate (mid term) P.5 NaCSA, CIBA (Immediate -regular basis)
Seasonal Changes	• Rainfall variation (salinity, pH and DO changes and increased disease problems) • Crop season delays • Temperature variation, (moulting problems, Low/no feeding and slow growth) • Brood stock quality and quantity decline	P.1 Regular monitoring of water quality parameters (Tech Advice) P.2 Preventive measures for disease monitoring-probiotics usage P.3 Pond depth increase, no over feeding, DO increase (Tech advice) P.4 alternate species like seabass, quality seed and feed P.5 BMPs, Maintenance of water level, Induced moulting, Lime P.6 Brood stock bank, SPF	P.1 Farmers through private labs, R&D Institutes(Regular basis) Immediate P.2 CIBA, Labs (Regular basis) P.3 DoF, NaCSA, local feed (Regular basis) companies P.4 CIBA, CMFRI (Short term – 1 to 2 years) NaCSA and CAA P.5 CIBA, NaCSA (Immediate) P.6 RGCA, NFDB (Short term – 1 to 2 years)
Low temperatures	High disease	P.1 Disease surveillance P.2 Feed monitoring	P.1 CIBA (Immediate) P.2 CIBA, DoF, NaCSA (Immediate)
Low tidal movement	Difficulty water exchange	P.1 Improving the pumping efficiency	P.1 Electricity Dept, NaCSA, CIBA (Immediate)

C. Institutional/Policy measures by Policy group

Climate change	Adaptation measures based on priority (P)	Responsible agency for implementing the measures
Flooding	P.1 Crop insurance P.2 Flood alert/flood information P.3 Strengthening of pond bunds P.4 Discourage culture in river bed P.5 Nets around the pond bunds P.6 Free board should be maintained P.7 Financial support for deepening of ponds and to elevate the height of ponds P.8 Evacuation of inhabitations in drains / canals for easy drainage P.9 Support to provide insurance to all small and marginal farmers P.10 Quality seed and feed supply P.11 Awareness about not to use pesticide to save pollution through seepage into ponds. P.12 Vegetation / plantation on ponds bunds – giving awareness to farmers	P.1 Govt. Secretary Agriculture Dept. P.2 District Administration from IMD P.3 DOF/NaCSA P.4 Fisheries dept / MPEDA / NaCSA P.5 NaSCA/DoF/CIBA P.6 DoF/farmer P.7 Do F 9Govt.) P.8 Irrigation Department P.9 Government P.10 Govt./hatcheries/Feed companies/CIBA P.11 NACSA/Pollution Control Board P.12 DOF/NaCSA
Seasonal change / low temperature	P.1 Quality seed P.2 Effective communication system P.3 Announcement of crop calendar - clear cut direction for aquaculture crops (summer / winter) P.4 Three to four weather monitoring stations for each mandal	P.1 Seed Act implementation by DOF P.2 DOF / MPEDA P.3 DoF/NaCSA P.4 District Administration/IMD
Low tidal movement	P.1 Deepening of water bodies P.2 Bank loan reschedule P.3 Maintenance of water level – awareness about water exchange P.4 Time to time clearing of bar mouth P.5 Separate intake and drainage canals P.6 Authority to take care of maintenance of creeks and drains	P.1 Govt. P.2 Govt. and Banks P.3 DOF P.4 Irrigation Department P.5 Irrigation Department P.6 DOF

High temperature	P.1 Strict implementation of quality control / standard norms on hatcheries – (SPF may not affect by high temperature) P.2 Shelter belt plantations and mangrove plantation on bunds P.3 Advance information on weather P.4 Subsidy by Govt. to deepen ponds to increase water level P.5 To maintain at least 1.2 m water depth – should be one of the CAA guidelines	P.1 CAA P.2 Forest Department/DoF P.3 IMD P.4 DoF P.5 CAA guidelines/NaCSA
Drought / low rainfall	P.1 District level planning for water budgeting for aquaculture P.2 Drought relief measures to be taken up on the lines of agriculture sector including cash compensation P.3 Alternative species that should survive in the low rainfall	P.1 Irrigation/(Agriculture/Fisheries Department P.2 Department of Fisheries P.3 Fisheries Research Institutes
Heavy rainfall	P.1 Activation of groups of small farmers to take up community activities to mitigate loss. P.2 Free board is must	P.1 NaCSA P.2 DoF/Farmer
Cyclone	P.1 Forecast – Advance early warning system P.2 Shelter belt casuraina plantation on the coast – by forest dept	P.1 IMD/District Administration P.2 Forest Department

ANNEXURE –V
(Confidential)

QUESTIONNAIRE ON FARMER PERCEPTIONS OF CLIMATE CHANGE IMPACTS TO SHRIMP FARMING IN KRISHNA DISTRICT, ANDHRA PRADESH, INDIA

Aqua Climate **PROJECT**

Definition of climate change: *Climate change is a significant variation in the mean state of the climate or its variability, persisting for an extended period (typically decades or longer)* **(IPCC)**

Privacy statement: *All information about individuals will be kept confidential and will not be distributed to any other organisation or entity. Only summary statistics will be published where individual farmers cannot be identified.*

Respondent name:____________________________Phone number:_______________

Interviewer name: _____________________________ Date: _______________________

Village:	**Mandal :**	
GPS READING AT SLUICE GATE OR PUMP INLET TO FARM IF NO SLUICE GATE UTM	**N**	**E**

PART A: GENERAL PROFILE OF THE RESPONDENT'S HOUSEHOLD

A1	Respondent status ( ) 1. Owner and operator ( ) 2. Caretaker ( ) 3. Other;___________
A2	Age (Completed years):
A3	Gender ( ) 1. Male ( ) 2. Female
A4	Number of household members:______ (Male:______, Female: ___________)
A5	Number of household members involved in farm: ______ % time Male:______, Female: ____% time involved)
A6	Number of household members who earn income: _____ (Male:______, Female: ____)
A7	Respondent's main occupation (based on time spent):
A8	Number of years in shrimp culture of respondent: (Farming Experience in years):
A9	Level of education of the respondent ( ) 1. Primary (1-5):____ ( ) 2. Secondary (6-10): ____ ( ) 3. Tertiary (>10): _____
A10	Number of shrimp farming training courses attended? _____
A11	Are you a member of an association? ( )0. No ( )1. Yes, If yes specify name and assistance provided: Name: ____ Assistance provided: ____

PART B: FARM INFORMATION

B1	Number of shrimp farms (not ponds) owned by the farm owner:	
B2	Type of improved extensive farm (visited farm) (can choose more than one)	
	( ) 1. Shrimp	Species:
	( ) 2. Rice	Variety:
	( ) 3. Coconut	Variety:
	( ) 4. Scampi/Fish	Species:
	( ) 5. Others:	Species:
B3	When was the visited farm established as a shrimp farm (Year):	

B4	Visited farm land ownership ( ) 1. Owned ( ) 2. Leased	
B5	Farm size	
	B5.1	Total area of visited farm (all farm area) (ha):
	B5.2	Water spread area (ha):
B6	Number of shrimp ponds in the visited farm:	
B7	Shrimp pond information of visited farm (if no trench answer 1,2,3, 4 and 5 and if there is a trench, answer all)	

Complete for all types of ponds						Complete only for ponds with trench			
Pond No.	(1)Pond area (ha)	(2)Length (m)	(3)Width (m)	(4)Height of dyke from pond bottom to the top of dyke (m)	(5)Height of water level from the pond bottom (m)	(6)Height of dyke (bottom of trench to the top of dyke) (m)	(7)Height from bottom of trench to the pond bottom (m)	(8)Height of water level from the bottom of the trench (m)	(9)Width of trench (m)
1									
2									
3									
4									

B8	Do you have outside dyke (in addition to the pond dyke)? ( ) 0. No ( ) 1. Yes, If yes, How high _____ (m) for what purpose? _________________________
B9	Source of water supply in visited farm (Specify % of the total amount (total =100%) (%) 1. Canal (man made) (%) 2. River/Creek (natural) (%) 3. Estuary (natural) (%) 4. Sea (%) 5. others: specify:_____________________________
B10	How far away are your ponds from your water source (meters)?_____________________
B11	Method of getting water into visited farm (Specify % of the total amount (total =100%) (%) 1. Gravity/tidal (%) 2. Pumping by using ( ) A. diesel ( ) B. bio-diesel ( ) C. electricity ( ) D. other:______ (%) 3. others: specify:________ If pumping what is the horse power of engine?
B12	Are there systems of inlet water filtration and sedimentation (i.e. filter screens, Reservoir pond, filter bags etc..) in visited farm? ( ) 0. No ( ) 1. Yes: specify,______________________________
B13	What is the salinity of inlet water? What is the salinity variation/range during the culture period? In Summer crop (Jan-June): _______________ ppt, Range : …………ppt In Monsoon crop (July-Dec): ___________________ppt' Range : …………ppt
B14	Do you use aeration in the pond? ( ) 0. No ( ) 1. Yes, specify (e.g., paddy wheel/long-arm): ___________________; No/ha.--------- If yes, how many hours per day is it used at start _______ hrs, during _______ hrs, at end _______ hrs If yes, how is it powered? ( )1 diesel ( )2 bio-diesel ( )3 electricity ( ) 4 other:______ What is the horse power of engine?

B15	Changing water (renew culture water) during culture (% per month) ( ) 0. No ( ) 1. Yes: In Summer crop: ___________(%), In Monsoon crop: ______________ (%), In monsoon season pumping out to compensate for rainfall only _________(%)
B16	How many times do you exchange water per crop? In Summer crop: ___________ In Monsoon crop: ______________
B17	Is there a system of waste water treatment during the culture period in visited farm? ( ) 0. No ( ) 1. Yes: specify, ________________________________
B18	Can and do you completely drain the pond **during harvest** ( )0. No ( ) yes. Can and do completely dry the pond ( )0. No ( ) yes; Before you start to dry your pond how deep was the sludge? (cm)________________ For how many days do you dry your pond each time you dry it? _________________days
B19	Is there a system of waste water treatment during pond draining at harvest in visited farm? ( ) 0. No ( ) 1. Yes: specify, ________________________________
B20	Method of getting water out of the visited farm? (Specify % of the total amount (total =100%)) (%) 1. Gravity/tidal %) 2. Pumping by using ( )A. diesel ( )B. bio- diesel ( )C. electricity ( ) D. other:______ (%) 3. others: specify:________
B21	Where does the water from the visited farm go? (Specify % of the total amount (total =100%)) 1. (%) 1. Canal (man made) (%) 2. River/ Creek (Natural) (%) 3. Estuary (Natural) (%) 4. Sea (%) 5. others: specify:_____________________________
B22	During culture period, do you remove sludge/sediment? ( ) 0. No ( ) 1. Yes: If yes, how do you get rid of your sludge? Bottom discharge ( ) By gravity ( ) By pump ( ) Manual ( )
B23	During the culture period where does the sediment from the visited farm go? (Specify % of the total amount (total =100%)) Manmade – canal; Natural – River/Creek, estuary (%) 1. Canal (%) 2. River/Creek (%) 3. Estuary (%) 4. Sea (%) 5. Dyke consolidation (%) 7. Fertiliser (%) 8. Others, Specify:____________________________
B24	During **pond preparation** where does the sediment/sludge from the visited farm go? (Specify % of the total amount (total =100%)) (%) 1. Canal (%) 2. River (%) 3. Estuary (%) 4. Sea (%) 5. Dyke consolidation (%) 7. Fertiliser (%) 8. Others, specify: _________________
B25	If you do not use the sediment/sludge for dyke consolidation, **why and what** material/method do you use for the dyke consolidation? Why? ____ What do you use?____
B26	Do you plant trees or vegetation on your dyke? ( ) 0. No ( )1.Yes If yes what tree/plant_______________ and for what? Dyke stabilization/wood/income/Other: ____

PART C: VISITED FARM PRODUCTION INFORMATION (for 2009 summer and monsoon crops)

		Summer crop **Month ____to _______** **(Total = _____ months)**	**Monsoon (Winter) crop** **Month ______ to _____** **(Total = ______ months)**
POND PREPARATION including sediment removable (for all productions)			
C1	Pond preparation (which months?)		
C2	Sediment removable cost (Rs/crop/ha)		
C3	Dyke/canal repairing (Rs/year)		

C4	Sluice gate repairing (Rs/year)		
C5	Other costs specify: _________________ (Rs per crop)		
	Chemicals		
C6	Lime amount (kg/ha/crop)		
C7	Lime cost (Rs/kg)		
C8	Total cost of other chemical (Rs/ crop) (specify chemical: e.g., Formalin, Bleaching powder ____)		

C9	**Fertilizer usage (Am. – Amount)**														
Summer crop								Monsoon (Winter crop)							
Organic fertiliser				Inorganic fertiliser				Organic fertiliser				Inorganic fertiliser			
Type1		Type 2		Type1		Type 2		Type1		Type 2		Type1		Type 2	
Am. (kg/ crop)	Cost (Rs/kg)	Am. (kg/ crop)	Cost (Rs/kg)	Am. (kg/ crop)	Cost (Rs/kg)	Am. (kg/ crop)	Cost (Rs/kg)	Am. (kg/ crop)	Cost (Rs/kg)	Am. (kg/ crop)	Cost (Rs/kg)	Am. (kg/ crop)	Cost (Rs/kg)	Am. (kg/ crop)	Cost (Rs/kg)

	CULTURE PERIOD (for all productions)	**Summer crop**	**Monsoon (Winter) crop**
C10	Feed amount (kg/ crop) Name of commercial brand:____________________	Commercial (branded) (% protein):___ Non-branded: ____________	Commercial (% protein): ____ Non-branded: ____________
C11	Feed cost (Rs/kg)	Commercial:____________ Non-branded:____________	Commercial: ____________ Non-branded: ____________
C12	Drug cost, e.g., probiotic, anti-biotic specify:____________________________		
C13	Type of fuel:____________________ Fuel amount (Liter/ crop)?		
C14	Fuel cost (Rs. per liter)		
C15	Electricity running time (hr/crop)		
C16	Total electricity cost (Rs/ crop)		
C17	Hired labor amount (days)		
C18	Hired labor cost (Rs per day)		
C19	Others: specify:______________________		
SHRIMP			
C19	Stocking month?		
C20	Stocked number of PL (per farm or per ha)		
C21	Stock size (PL size)		
C22	Seed cost (Rs/PL)		
C23	Harvest month		
C24	Harvest amount (kg)?		
C25	Harvest price and proportion (%) of each size		
	C25.1 Small:_____________ pcs/kg	_______Rs/kg (%)	_______Rs/kg (%)
	C25.2 Medium:___________ pcs/kg	_______Rs/kg (%)	_______Rs/kg (%)
	C25.3 Large: _____________ pcs/kg	_______Rs/kg (%)	_______Rs/kg (%)
C26	Total income from shrimp harvest (Rs/crop)		
C27	Where do you sell the shrimp (% of crop) (Total = 100%)	(%) 1. Processor (%) 2. Middlemen (%) 3. Local market (%) 4. Others:_____________	
C28	What are the main causes of shrimp losses and how much loss in Rs? (1=major lost)	1. ____ 2. ____	

		3. ____ 4. ____

		Dry season for shrimp only	Wet season for shrimp OR rice season for shrimp+ rice
Paddy size: _________ (Ha)			
C29	Start planting (specify months?)		
C30	Total paddy seeds (Rs per crop)		
C31	**All** other cost for paddy: specify:_____________		
C32	Harvest month (specify months?)		
C33	Total harvest amount (kg/ crop)		
C34	Paddy price (Rs/kg)		
C35	Total income from paddy (Rs/crop)		

COCONUT			
C36	No. of trees (per ha)		
C37	Income/tree/year		
C38	Total income from coconut (Rs.)		
Scampi/Fish/crab farming			
C39	Stocking month?		
C40	Stocked number		
C41	Stock size		
C42	Seed cost (Rs/PL)		
C43	All other costs for Scampi/fish/crab: specify:____		
C44	Harvest month		
C45	Harvest amount (kg)?		
C46	Total harvest amount (kg/ season)		
C46	Average Scampi/fish/crab price (Rs/kg)		
C47	Average scampi/fish /crab size (number/kg)		
C48	Total income from scampi/fish /crab (Rs/crop)		
OTHER COSTS			
C49	Land tax/fee (Rs per year)		
C50	Land lease (Rs per year)		
C51	Do you have a loan and how much is the current amount (related to shrimp culture)		
C52	Loan interest (rate ____%)(related to shrimp culture) (Rs per year)		
C53	Type of loan (Commercial Bank, Cooperative, Micro Finance Institution, Private Lending Institution, Other specify)		
C54	Others costs (Rs/year): specify:__________________________		

D. SOCIO-ECONOMIC PROFILE OF THE RESPONDENT'S HOUSEHOLD

D1	Different sources of respondent's household income in Rs/Year ( ) 1. Shrimp farming: _________ ( ) 2. Fishing: ___________ ( ) 3. Agriculture: ________ ( ) 4. Hired labour _______________________ ( ) 5. Others: Specify: ________________Rs/Year
D2	Annual expenditure pattern of the respondent (Rs) 1. Food _____ 2. Clothes ____ 3. Education of children ____ 4. Health/hospital _____ 5.Entertainment ____ 6. Travel ____ 7. Savings _____ 8. Others (Please specify type) ________________
D3	Type of house - 1. Kachha/Pucca 2. Temporary/Permanent

D4	Material possession 1. Vehicles - type & number ___________ 2. Costly home appliances __________ 3. Others (Pl.specify) _______

PART E: CLIMATE CHANGE PERCEPTION

Use these tables for answer part D1 CONSEQUENCE AND ADAPTATION FRAMEWORK

Likelihood Scales

Rating	Likelihood
5 = Almost Certain	Could occur several times per year (for example storms)
4 = Likely	May arise about once per year
3 = Possible	May arise once in ten years
2 = Unlikely	May arise once in 10 years to 25 years
1 = Rare	Unlikely to occur during the next 25 years (for example direct hit from typhoon)

Consequence Scales

Rating	Economic consequence
5 = Exemeley positive	Extreme increase in profitability
4 = Major	Business thrives
3 = Moderate positive	Significant general increase in economic performance relative to without climate change
2 = Minor positive	Individually significant but isolated areas of reduction in economic performance relative to without climate change
1 = insignificant positive	Minor increase in profitability relative to without climate change
0 = No consequence	No positive or negative impacts
-1 = Insignificant negative	Minor shortfall in profitability relative to without climate change
-2 = Minor negative	Individually significant but isolated areas of reduction in economic performance relative to without climate change
-3 = Moderate negative	Significant general reduction in economic performance relative to to without climate change
-4 = Major negative	Business are unable to thrive
-5 = Catastrophic	Business failure

positive implications please also explain in table E1. (for example: new species can be cultured, more income from farming or byproducts (fertiliser), more areas available for culture, pumping cost reduced etc...)

PART E1. CONSEQUENCE AND ADAPTATION: In last 10 years

Climate change Explain what change (i.e. Irregular season: rain in dry season)	Observed in your area (yes or no)	If there was impact/consequence (positive or negative) on your farm, please answer Likelihood & Consequence questions below, for RATING, please rate by using tables above				Adaptation		
		Likelihood/ frequency	Consequence					
		Rating (1-5)	Rating (-5 to +5)	Production gain/loss or farm improve/damage?*	Economic gain or loss (Rs)	Measures used **	Cost of measures (Rs)	Level of success (0 not success, 10 problem solved)
E1.1 Irregular season: _________________								
E1.2 Temperature rapid change: _________________								
E1.3 Temperature (high): _________________								
E1.4 Temperature (low): _________________								
E1.5 Cyclone/storm: _________________								
E1.6 Heavy rain: _________________								
E1.7 Floods from rain: _________________								
E1.8 Drought: _________________								
E1.9 Water salinity increase: __________								
E1.10 Water salinity decrease: __________								
E1.11 Tidal surge/flood (sea /river/canal level rise) If yes by how much change +/- _____cm Tidal surge no. times _____ & years observed: ____________								
E1.12 Other: ________________								

Climate change Explain what change (i.e. Irregular season: rain in dry season)	Observed in your area (yes or no)	If there was impact/consequence (positive or negative) on your farm, please answer Likelihood & Consequence questions below, for RATING, please rate by using tables above				Adaptation		
		Likelihood/ frequency	Consequence					
		Rating (1-5)	Rating (-5 to +5)	Production gain/loss or farm improve/damage?*	Economic gain or loss (Rs)	Measures used **	Cost of measures (Rs)	Level of success (0 not success, 10 problem solved)
E1.13 Other:____________________								
E1.14 Other: ___________________								

*for **positive implications** please also explain in table E1. (for example: new species can be cultured, more income from farming or byproducts (fertiliser), more areas available for culture, pumping cost reduced etc...)

****examples of adaptive measures**: Changed farming practices (feeding practices, adjust harvesting, post-harvesting and distribution strategies, adjust stocking densities, introduced new species), change farm infrastructure (increase dyke height, deeper ponds, shade pond), Shifted to other occupations, Got help (government, NGO, family, others), others, specify________

PART E2: ADAPTABILITY

Answer the following from part E1 (above table)

		What ?	Why?/How?
E2.1	The most difficult losses due to climate changes to overcome		
E2.2	climate changes that has become stronger and/ or more frequent		
E2.3	climate changes has become weaker and/ or less frequent		

E2.4	Please RANK who helped you most when you had serious losses on your farm due to any climate changes that you listed in Part E1 or other reasons in the last 3 years	
	_____ 1. Government agencies	___ 2. Village authorities'
	_____ 3. Friends and family	___ 4. Own sources (themselves)
	_____ 5. Private agencies	___ 6. Others, specify:______________
E2.5	Please RANK the following support from the government /agencies in last 3 years related to shrimp farming that you received	
	_____ 1. Material support (post larvae, feed, equipment)	___ 2. Financial support (grants, subsidies, loans)
	_____ 3. Technical support	___ 4. Training (skills development)
	_____ 5. Others, specify:	
E2.6	What do you think are going to be the most important <u>impacts</u> due to climate change in the next 5-10 years (This is the likelihood)	
	1:.________________________________	2.____________________________________
	3. ________________________________	4.____________________________________

E2.7	Are you planning to use new measures in next few years in farming / due to the climate changes mentioned in Part E1 (specify what measure for what climate change?)		
	New measures	**For what climate change?**	**Do you think that these will be sufficient to cope with the change (yes or no and why?)**
	( ) 0. No changes		
	( ) 1. Changing farming practices		
	( ) 2. Farming new species		
	( ) 3. Bunds/dyke, other structures		
	( ) 4. Other:		
	( ) 4. Other:		

E2.8	Have you attended any skills training related to shrimp farming or climate change in 2008/2009? ( ) 0. No ( ) 1. Yes, specify:
E2.9	If YES in E2.8, please answer E2.9

Type of training	Who organised?	Effective (Yes or No) and Why?	Helped to improve your farm (Yes or No) and why?	More such training should be conducted? (Yes or No) and why?

<table>
<tr><td rowspan="2">E2.10</td><td colspan="4">Which agencies are most capable or influential to provide support to farmers (rank 1 to 4) (State Govt., Central Govt., NGOs, University, Research Institutes, Farmers agencies/ groups) and why?</td></tr>
<tr><td>1
Why?</td><td>2
Why?</td><td>3
Why?</td><td>4
Why?</td></tr>
<tr><td rowspan="6">E2.11</td><td colspan="4">For each measure, do you think that it would be effective to overcome climate change impacts or losses? If yes then rank how effective you think they will be?</td></tr>
<tr><td colspan="2">Measures</td><td>Effective (yes or no)</td><td>If yes, ranking Effectiveness</td></tr>
<tr><td colspan="2">Improve technical & information support (training or awareness)</td><td></td><td></td></tr>
<tr><td colspan="2">Improve financial support /improve credit access, loan waivers, insurance, relief</td><td></td><td></td></tr>
<tr><td colspan="2">Increase level of farmer's participation in climate change management</td><td></td><td></td></tr>
<tr><td colspan="2">Others, specify:</td><td></td><td></td></tr>
<tr><td>E2.12</td><td colspan="4">What is the biggest problem/challenge in running your farm, NOW? Choose one
(   ) 1. Weather related, specify: ________________________________
(   ) 2. Non-weather related, specify: ________________________________</td></tr>
<tr><td>E2.13</td><td colspan="4">What will be your biggest problem in running your farm in FUTURE? Choose one
(   ) 1. Weather related, specify: ________________________________
(   ) 2. Non-weather related, specify: ________________________________</td></tr>
<tr><td>E2.14</td><td colspan="4">How long do you think that you will be still farming in the future? __________years or indefinitely. Why________________________________</td></tr>
</table>

PART F: CLIMATE CHANGE MITIGATION

F1	What proportion of fuel can you reduce without a reduction in production? (%). What are the compensatory BMPs?
F2	What is the impact on your production (in kg) and profitability if you had to reduce your fuel consumption by 50% (estimate)? Product (i.e. shrimp, rice etc…): ___________ reduction in harvest _________ kg ; reduction in income: _____________Rs
F3	What proportion of electricity can you reduce without a reduction in production or profitability? (%) What are the compensatory BMPs?
F4	What is the impact on your production (in kg) and profitability if you had to reduce your electricity consumption by 50% (estimate)? Product (i.e. shrimp, rice etc…): ___________ reduction___________ kg ______Rs
F5	How much of fuel use can be replaced with electricity in your farm?
F6	Are you using a windmill or other device (specify _______________) that does not use fuel or electricity to supply some of your pumping and or electricity needs? If not could you 1. Yes ( ) 2. No ( ). If you do or could what percentage could you supply using this alternative method? (%)
F7	Can you use bio-diesel instead of regular fuel? ( )0. No ( )1. Yes
F8	If you grow paddy, do you practice burning the paddy stubble or paddy husk after harvesting? ( )1. Yes ( )0. No, if not why __________________