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Adaptation to Climate Change and Livelihoods: An Integrated Case Study to Assess the Vulnerability and Adaptation Options of the Fishing and Farming Communities of Selected East Coast Stretch of Tamil Nadu, India

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Local adaptation to climate change impacts are increasingly observed across communities. This study is focused on the assessment of vulnerability to climate change and documents the adaptation practices relevant to two sectors namely, farming and fishing in two selected coastal districts of the East coast stretch of Tamil Nadu state in India with special reference to the local livelihoods. This study takes a case study approach examining both the effectiveness of adaptation options and the prevailing constraints in implementing the adaptation strategies. Besides the analysis of past climate data for the study area, in-depth interviews and focus group discussions are key methodology used to elicit information. This paper offers an adaptation framework that is relatively simple capturing both the effectiveness and constraints of adaptation options that are in vogue in the study area covering the two important livelihood sectors farming and fishing.

Keywords: Agriculture, Fishery, Exposure, Livelihood sensitivity, Local adaptation framework.

1. Introduction

The existing climatic impact studies highlight that both agriculture and fishery sectors are highly sensitive to the impact of climate change,[1–8] particularly in developing nations like India.[9–17] Since a larger proportion of people, especially in

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the developing nations, are depending on these sectors for their basic livelihoods, climate change is therefore likely to have negative welfare implications now and forever. The existing political, economic, social and environmental factors within a system play a critical role in either increasing or decreasing vulnerability arising out of climate change. At the same time, the poor and the vulnerable people have used different adaptation measures (e.g. autonomous and planned) to smoothen consumption.

In the recent decade, adaptation has been recognized as an effective option to reduce the negative impact of climate change.[18–20] In the climate change discourse, adaptation means an adjustment in human and natural systems to actual or expected climatic stimuli, which can reduce negative impacts and take advantage of the positive,[21],[a]. After the COP-13 Bali 2007[b], a wide range of studies have emerged to estimate both macro and micro level adaptation cost,[21],[c] based on hypothetical adaptation options. However, these studies have assumed that everybody is inclined to choose adaptation options, which could be a mal-adaptive option as it does not account feasibility of such intervention in the given social, economic, political and institutional settings. There is a serious lack of information on understanding locally driven vulnerability, micro-level sustainable adaptation practices[25,26,27] and relevant constraints.[28–33] Increasingly such information is much more relevant for the successful implementation of adaptation strategies at micro level. In this context, Eriksen et al.[28] emphasized on understanding of the relationship between present day coping and vulnerability, which will assist policy makers to design appropriate adaptation policy. Thus, the present study therefore examines causes of locally driven vulnerability and also understands current adaptation options, effectiveness and associated barriers in both agriculture and fishery sector.

For this purpose, this study purposively selected two coastal districts of Tamil Nadu, India, namely Cuddalore and Nagapattinam. Scholarly studies have reported that the coastal district of India are highly susceptible to a large number of extreme events associated with the climate change.[34–37] Further, the Bay of Bengal is one of the six regions in the world where severe tropical cyclones originate,[38],[d]. In particular, these two selected coastal districts are geographically situated at the head of the Bay of Bengal and experience extreme events associated with the climate change more frequently.[38,40,41] In these two districts, agriculture and fishery is the main source of livelihoods for the local communities. Since both

[a]For different definitions on adaptation.[20,22]

[b]In this negotiation meeting, the developed nations have agreed to 'provide adequate, predictable, sustainable financial resources, including official and concessional funding, for developing country parties in order to adapt to the climate change'[23].

[c]The objective of these studies is to calculate 'price tag' for adaptation to help policy makers in the global, regional and local context.[24]

[d]Out of the total cyclonic disturbances passes through both the Bay of Bengal and the Arabian Sea, 85.48 percent of the cyclonic events are passes through the Bay of Bengal.[39]

the sectors are highly sensitive to climate change, the people whose major share of income is derived from these sectors have to undertake appropriate adaptive measures to buffer current and expected climatic stimuli.

This study outlines an adaptation framework to draw out implications with regard to vulnerability of agriculture and fishery sectors, and means by which that vulnerability might be reduced, while highlighting the barriers of adaptation; the approach combining these two components is called as integrated vulnerability assessment.[42–45] In this context, the study first maps severity of climate variation and extreme events in Tamil Nadu, especially in Cuddalore and Nagapattinam districts, and sensitivity of coastal farm and fishing households in these two selected districts. Subsequently, it investigates both performance and constraints of adaptation options to provide pointers for appropriate adaptation measures at the local level.

2. Description on Study Area

The state of Tamil Nadu is the southernmost state of India, which is geographically situated at the Indian Ocean on the south and the Bay of Bengal on the east. It has 13 coastal districts covering a coastal length of around 1076 km, which is the second largest sea coast and constitute about a 15 percent of the total coastal length of India. Tamil Nadu coast is highly vulnerable to a wide range of the climate change related events, particularly cyclones and floods that cause inundation of low lying coastal areas resulting in damages to crops and property.[46] As per Indian Meteorological Department (IMD),[39] nearly 11 percent of the total cyclonic storms generated in the Bay of Bengal are passing through the Tamil Nadu state. Of the

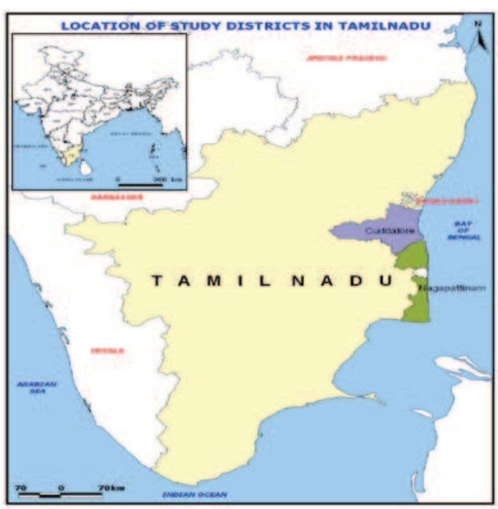

Figure 1 Location of Study Districts in Tamil Nadu.

total population, about 47 percent live in the coastal areas and their livelihoods mainly depend on agriculture and fishing activities (both marine and backwater fishing), which are highly susceptible to adverse climatic conditions.

Cuddalore district is located at the east coast of Tamil Nadu in Indian peninsula (see Figure 1). It is geographically located between 11°11′ and 12°35′North latitude and between 78°38′ and 80° East longitude on the coast of Bay of Bengal. It covers an area of 3,678 km^2 with a total population of 2.6 million (as per census 2011) and population density of 702[47] (higher than the Tamil Nadu state, i.e. 555, and 13.77 percent increase as compared to the 2001 Census), and out of the total population, 66.99 percent of the people live in the rural areas. In particular, 65.26 percent of people are depending on agriculture for their livelihood, and HDI (human development index) is 0.644[48] (marginally lower than the Tamil Nadu state, i.e. 0.657) in the year 2001. It has a coastline of about 57.5 km, which is 5.34 percent of the total Tamil Nadu coast line. The coastal areas of Cuddalore has a gently sloping coastal topography with river streams (e.g. Gadilam, Ponnaiar, Vellar, Malathar, Uppannar, Khan Sahib Canal, Paravanar and Kolidam) draining into the Bay of Bengal in the Indian Ocean, which makes the district more prone to sea hazards. The coast has also a unique mangrove forest at Pichavaram[e] that acted as buffer against 2004 Indian Tsunami.[50]

Nagapattinam district is located at the head of the Bay of Bengal (see Figure 1). It is geographically situated between 10°10′ and 11°20′ North latitude and between 79°15′ and 79°50′ East longitude on the coast of Bay of Bengal. It covers an area of 2715.83 km^2 with a total population of 1.61 million (as per census 2011) and population density 668[51] (not only higher than Tamil Nadu state but also 8.42 percent increase as compared to the 2001 Census), and out of the total population, 77.82 percent of the people live in the rural areas. In particular, 81.95 percent of people are depending on agriculture for their livelihood, and HDI is 0.65448 in the year 2001 (almost equal to that of the Tamil Nadu state). It has a coastline of about 187.9 km, which is 17.46 percent of the total Tamil Nadu coast line. Unfortunately, most areas of this district are situated either below sea level or between 0–5 m above the sea level. Therefore, there is a high probability of sea water intrusion that leads to salinization of soil and ground water, and particularly such a situation is likely to be high because of complete lack of drainage system over a large stretch of land in the Cauvery delta area.

3. Data and Methods

This study has collected information from both secondary and primary sources to assess vulnerability of Cuddalore and Nagapattinam districts. First, it has

[e]Total area of the mangrove wetland is about 1470 ha, consisting of about 50 small islands which are colonized by mangrove vegetation.[49]

Table 1 Method of Selecting Study Village.

Name of District	Name of Taluk	No. of Total Revenue Villages	No. of Villages within 20 km from sea	No. of Villages form coast		No. of villages selected from coast		No. Villages selected for study
				0-5 km	6-20 km	0-5 km	6-20 km	
Cuddalore	Chidambaram	193	65 (33.68)	15 (23.08)	50 (76.92)	8	10	18 (27.69)
	Sirkali	94	42 (44.68)	10 (23.81)	32 (76.19)	5	7	12 (28.57)
Nagapattinam	Tarangampadi	70	31 (44.29)	8 (25.81)	23 (74.19)	4	5	9 (29.03)
	Nagapattinam	85	40 (47.06)	10 (25)	30 (75)	5	6	11 (27.5)
Total		442	178 (40.27)	43 (24.16)	135 (75.84)	22	28	50 (28.09)

Note: Figures in the parentheses indicate percentage figure.
Source: Taluk office (Chidambaram, Sirkali, Tarangampadi, and Nagapattinam)

assessed the exposure of the Tamil Nadu state, particularly two study districts, to climate variability and extreme events from the information collected from the IMD. The study has summarized livelihood sensitivity and adaptive capacity for both agriculture and fishery based on in-depth interviews and focus group discussions (FGDs) conducted in the different coastal villages of Cuddalore and Nagapattinam districts. The required secondary information was collected from district statistical handbooks of Tamil Nadu, Taluk office, published vulnerability reports and journal articles.

In order to gather primary information on livelihood sensitivity and adaptive capacity, the in-depth interviews and FGDs were conducted in the purposively selected four coastal Taluks[f], e.g. one in the Cuddalore district (i.e. Chidambaram) and three in the Nagapattinam district (i.e. Sirkali, Tarangampadi, and Nagapattinam). In particular, these Taluks are selected based on a set of criteria, i.e. (i) frequency of cyclone and coastal flood, (ii) geographical location (stretching up to 5 m above sea level) and (iii) population density in addition to discussions with different stakeholders in the study area. In the selected Taluks, a total of 178 revenue villages are falling within the 20 km distance from shoreline, and out of that 43 villages fall within 5 km distance and the rest of 135 villages fall between 6–20 km distance[g]. This study purposively selected 50 percent of the villages within 0–5 km distance (i.e. 22 villages) and 20 percent of the villages within 6–20 km distance (i.e. 28 villages) for in-depth interviews and FGDs (see Table 1). The sampling size for the villages within 5 km is high because it assumed that the villages near the coast are highly vulnerable. In Table 1, one can observe that 40.27 percent villages are within 20 km from the coast, whereas such figure is even high in the Taluk of the Nagapattinam district.

In the selected villages, the data were collected in three stages from January to March 2009, May to August 2009, and September 2011. Initially, this study has randomly selected 20 villages to conduct the FGDs, which is carried out during

[f]Taluk is an administrative division, which consists of a city that serves as it headquarters, possibly additional towns and a number of villages. It exercises certain fiscal and administrative power over the villages and municipalities within its jurisdiction.
[g]This information has been collected from the respective Taluk office.

the first phase of the survey, to get an overview of vulnerability and adaptive measures. After that, it has conducted an in-depth interview with individual farmer and fisherman (at least three either farmer or fisherman in each selected village) during second phase of the survey. In the third phase of the survey, revisits were made to some of the villages to clarify the earlier findings. Through this survey, a wide range of information was gathered on vulnerability and relevant adaptive measures. In each FGDs, nearly 10 participants were exactly chosen, and mostly dominated by male participants as they are mainly engaged in agriculture and fishing activities. Local (Tamil) language is used to conduct FGDs, and in-depth interviews. They were particularly asked to explain the vulnerabilities associated with their livelihoods due to climatic impact and enlist the adaptation options available to them to cope with such events including their effectiveness and constraints. In the villages near to coast (e.g. 0–5 km), the participation of people in the FGDs is mostly dominated by the fishermen, whereas a larger number of farmers participated in the villages situated beyond 5 km (i.e. 6–20 km)[h].

4. Analysis and Discussion

4.1. *Climate variation and extreme events*

In this section, the present study has analyzed long-term variation of meteorological parameters (e.g. sea level pressure, wind speed, rainfall, rainy days, minimum and maximum temperature) of Cuddalore and Nagapattinam districts for the period of 1950–2007, frequency of cyclonic storms and evidence of expected sea level rise in Tamil Nadu (see Table 2). The trends based on the assessment of the critical meteorological parameters are tabled here (see Table 2):

(i) *Sea level pressure:* it was shown a marginal increasing trend in the Nagapattinam district, whereas a marginal decreasing trend was found in the Cuddalore district. However, the trend of both the districts is not statistically significant.

(ii) *Wind speed:* in both the districts, the annual trend of wind speed was declining with the 1 percent significant level. Moreover, the standard deviation (SD) during cold weather period (CWP) is high in comparison to the annual and other seasons in the both districts. In particular, the wind speed was increasing during the south-west monsoon (SWM) period in both the districts.

(iii) *Rainfall:* in both the districts, the annual trend of rainfall was increasing, but it is statistically insignificant. The SD was high during 1950–70 in comparison to other periods in the both districts (see Table 2). Importantly, it is found that

[h]Because most of the people practicing fisheries in the coastal villages due to non-availability of suitable agricultural land to cultivate, and the villages beyond 5 km, a larger portion of people are engaged in agricultural activities.

Table 2 Analysis of Meteorological Data of Cuddalore and Nagapattinam Districts of Tamil Nadu (1950–2007)

Sl No.	Meteorological Parameter	Cuddalore	Nagapattinam
1	Sea Level Pressure	*Mean:* 1010.3 mbar (during CWP and HWP, SD is high in comparison to annual, SWM and NEM, e.g. 0.766 and 0.673 respectively). *Annual Trend:* Marginal ↓. *Seasonal Trend:* CWP- Marginal ↑; HWP- Marginal ↓; SWM- Marginal ↑; and NEM- Marginal ↑. • Statistically no significant trend.	*Mean:* 1010.5 mbar (during CWP and HWP, SD is high in comparison to annual, SWM and NEM, e.g. 0.767 and 0.661 respectively). Annual Trend: Marginal ↓ Seasonal Trend: CWP, HWP, NEM & SWM – Marginal ↓ • Statistically no significant trend.
2	Wind Speed	*Mean:* 12.32 kmph (SD is high during CWP, i.e. 4.299 in comparison to annual and other period). *Annual Trend:* ↓ (-0.078***). *Seasonal Trend:* CWP ↓ (-0.220***), HWP ↓ (-0.084***), SWM ↑ (0.041***), and NEM ↓ (-0.137***)	*Mean:* 12.17 kmph (SD is high during CWP, i.e. 4.472 in comparison to annual and other period). *Annual Trend:* ↓ (-0.089***) *Seasonal Trend:* CWP ↓ (-0.237***), HWP ↓ (-0.097***), SWM ↑ (0.033***), and NEM ↓ (-0.144***)
3	Rainfall	*Mean:* 1324.69 mm; • Mean rainfall is high during 1971-90, e.g. 1413.68 mm, whereas SD is high during 1950-70, i.e. 505.7. • Minimum rainfall is high during 1991-07, i.e. 825.6 mm, whereas maximum rainfall is high during 1950-70, i.e. 2524.9. • During 1991-2007, minimum rainfall for SWM is very low, i.e. 12.8 mm, whereas it is high for NEM, i.e. 631.4. *Annual Trend:* ↑ (but statistically not significant) *Seasonal Trend:* CWP ↑, HWP ↑; SWM- slight ↑, and NEM ↑ • Statistically no significant trend. • Nearly 69 percent of the annual rainfall has occurred during NEM, followed by 18.91 percent during SWM.	*Mean:* 1334.56 mm; • During 1950-70, SD is high, i.e. 512.74 • Minimum rainfall is high during 1991-07, i.e. 825.6 mm, whereas maximum rainfall is high during 1950-70, i.e. 2524.9. • During 1991-2007, minimum rainfall for SWM is very low, i.e. 12.8 mm, whereas it is high for NEM, i.e. 631.4. *Annual Trend:* ↑ (but statistically not significant) *Seasonal Trend:* CWP ↑, HWP ↑, SWM ↓, and NEM ↓ • Statistically no significant trend. • Nearly 69 percent of the annual rainfall has occurred during NEM, followed by 18.87 percent during SWM.

Contd.

Table 2 *Contd.*

Sl No.	Meteorological Parameter	Cuddalore	Nagapattinam
4	Rainy Days	*Mean:* 53.61 days *Annual Trend:* ↑ (but statistically not significant) • *Seasonal Trend:* CWP ↓, HWP- marginal ↑, SWM ↓, and NEM ↑ Statistically no significant trend.	*Mean:* 53.63 days *Annual Trend:* Marginal ↓ (but statistically not significant) • *Seasonal Trend:* CWP ↓, HWP- Marginal ↑; SWM ↓, and NEM ↑. Statistically no significant trend
5	Minimum Temperature	*Mean:* 25.16 0C (SD is high during CWP, i.e. .728). *Annual Trend:* Marginal ↓ (but statistically not significant) *Seasonal Trend:* CWP ↓ (-0.01*), HWP ↓ (-0.011***), SWM- Marginal ↑ (statistically not significant), and NEM- Marginal ↑ (statistically not significant).	*Mean:* 25.15 0C (SD is high during CWP, i.e. .716). *Annual Trend:* Marginal ↓ (but statistically not significant) *Seasonal Trend:* CWP ↓ (-0.012**), HWP ↓ (-0.011**), SWM Marginal ↑ (statistically not significant), and NEM Marginal ↑ (statistically not significant).
6	Maximum Temperature	Mean: 32.31 0C (Mean is high during SWM, i.e. 35.26 0C, whereas SD is high during CWP, i.e. 0.74). Annual Trend: ↑ (0.022***). Seasonal Trend: CWP ↑ (0.034***), HWP ↑ (0.020***), SWM ↑ (0.019***), and NEM ↑ (0.022***).	Mean: 32.35 0C (Mean is high during SWM, i.e. 35.3 0C, whereas SD is high during CWP, i.e. .796). Annual Trend: ↑ (0.025***). Seasonal Trend: CWP ↑ (0.038***), HWP ↑ (0.022***), SWM ↑ (0.021***), and NEM ↑ (0.024***).

Note: CWP means Cold weather period (January – February); HWP means Hot weather period (March – May); SWM means South-west monsoon (June – September); NEM means North-east monsoon (October – December); ↓ means Decreasing trend; ↑ means Increasing trend; figures in the parentheses indicate coefficient of time trend; and $***p < 0.01$, $**p < 0.05$, $*p < 0.1$ respectively.
Source: Analysis of data collected from Indian Meteorological Department (IMD)

there was a higher minimum rainfall during the period 1991–2007, whereas higher maximum rainfall was found during 1950–70. In the context of season-wise rainfall, the minimum rainfall during SWM was low and high during the north-west monsoon (NEM). Though the rainfall in each season had increased, their trend was statistically insignificant. In particular, nearly 70 percent of the annual rainfall has occurred during NEM and 20 percent in SWM in both the districts. It could be inferred that both the districts were getting their major share of rainfall during the NEM period.

(iv) *Rainy Days:* the annual trend of rainy days was increasing in the Cuddalore district and marginally decreasing in the Nagapattinam district, but the trend is statistically insignificant.

(v) *Minimum Temperature:* in both the districts, the annual trend of minimum temperature was marginally declining, but it is statistically insignificant. Moreover, the SD is high during CWP period. During both CWP and HWP (hot weather period), there was a marginal declining trend. Such figure, in contrast, is increasing during SWM and NEM periods with no statistical significance.

(vi) *Maximum Temperature:* in both the districts, the annual trend of maximum temperature was increasing (e.g. 0.0220C in Cuddalore and 0.0250C in Nagapattinam district with significance at the 1 percent level). While the mean was high during the SWM period, the SD was high during the CWP period. In particular, the maximum temperature trend was increasing in each season. There was a sharp increase during the CWP period (e.g. 0.0340C in Cuddalore and 0.0380C in Nagapattinam district with significance at the 1 percent level).

In addition, the Table 3 shows frequency of the cyclonic storms in the East-coast states of India, including the Tamil Nadu, based on the different study. Here one can find that the Tamil Nadu state has been experiencing cyclonic storms in the range of 11.21 percent to 25.58 percent.

Table 4 outlines decade wise frequency of cyclonic storms in both north and south of Tamil Nadu state during the period of 1891–2007. It is observed that northern Tamil Nadu has experienced nearly 6 cyclonic storms in each decade (e.g.

Table 3 Frequency of Cyclonic Events in the East-coast States of India

Sl No.	State	Mandal (1991)	GTECCA (1996)	SMRC (1998)	Mohanty and Gupta (2002)	IMD (2008)
	(1881–1989)	(1877-1995)	(1681-1996)	(1891-1994)	(1891-2007)	
1	West Bengal	69 (22.40)	67 (20.93)	33 (15.35)	49 (19.14)	149 (18.55)
2	Odisha	98 (31.81)	106 (33.12)	58 (26.98)	94 (36.71)	387 (48.19)
3	Andhra Pradesh	79 (25.64)	90 (28.12)	69 (932.09)	65 (25.39)	177 (22.04)
4	Tamil Nadu	62 (20.12)	57 (17.81)	55 (25.58)	48 (18.75)	90 9 (11.21)
5	Total	308 (100)	320 (100)	215 (100)	256 (100)	803 (100)

Note: Bracket parentheses are the percentage figure Source: SMRC (1998); Mohanty et al. (2008); and IMD (2008)[39,52,53]

Table 4 Frequency of Cyclonic Storms in Tamil Nadu

Period	Tamil Nadu North	Tamil Nadu South
1891–1900	3	0
1901–10	4	1
1911–20	4	1
1921–30	9	2
1931–40	12	0
1941–50	10	1
1951–60	8	1
1961–70	10	2
1971–80	3	3
1981–90	2	2
1991–2000	9	3
2001–07	1	0
Total (1891–2007)	75	16
Mean	6.25	1.33

Note: Source: IMD (2008)[39]

mean is 6.25), whereas southern Tamil Nadu experienced one significant storm in each decade (e.g. mean is 1.33). Therefore, it can be inferred that northern Tamil Nadu is experiencing a higher number of the cyclonic storms, and hence has a higher exposure the cyclonic storms in comparison to southern Tamil Nadu. Both the study districts are falling under the northern Tamil Nadu region, and thus it is highly exposed to the cyclonic storms. From Figure 2, it could be inferred that while there was a marginal declining trend of the cyclonic storm in northern Tamil Nadu, it was marginally increasing in southern Tamil Nadu.

Further, the Table 5 shows season wise frequency of the cyclonic storms in Tamil Nadu during 1891–2007. The figured indicate that a higher number of the

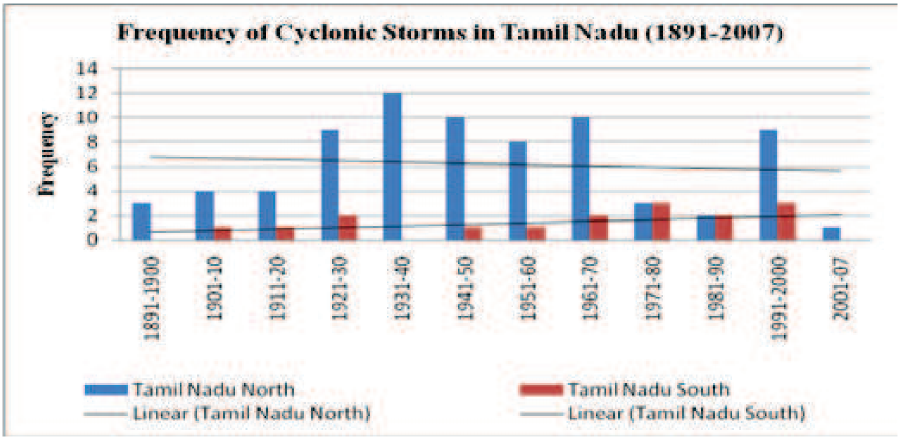

Figure 2 Frequency of Cyclonic Storms in Tamil Nadu (1891–2007).

Table 5 Season wise Frequency of Cyclonic Storms in Tamil Nadu

	No. of Cyclonic Storms (1891–2007)	
Season	Tamil Nadu North	Tamil Nadu South
CWP	2 (2.67)	1 (6.67)
HWP	9 (12)	1 (6.67)
SWM	0 (0)	0 (6)
NEM	64 (85.33)	13 (86.67)
Total	75 (100)	15 (100)

Note: Figures in the parentheses indicate percentage figure Source: IMD (2008)[39]

cyclonic storms occurred during the NEM period in comparison to the other periods, e.g. 85.33 percent in northern Tamil Nadu and 86.67 percent in southern Tamil Nadu. On the other hand, the recent study report[46] shows that the frequency of cyclonic storms will be high during post-monsoon season in the future scenario (2071–2100) in comparison to the baseline scenario (1961–1990) in the Bay of Bengal region. Further, the simulated rise in sea level by 46–59 cm along the Indian coastline by 2100 may have significant impact on the Cuddalore and Nagapattinam districts of Tamil Nadu state. Along the East coast districts of India, Nagapattinam has been a highly vulnerable region for the impact of storm surge.[46]

People are predominantly depending on fishing and agriculture for their basic livelihoods in the study areas. Given the critical role of the two sectors, this section attempts to focus on the sensitivity and implication for both fishing and farming communities.

4.2. *Sensitivity of fishing community*

In the coastal belt of the study area, fishing (marine and backwater) is the major source of livelihoods, more importantly marine fishing. For example, fishing is the mainstay activity in 60 coastal villages in the Nagapattinam and 4554 coastal villages in the Cuddalore district. Information from the Census conducted by the Department of Fisheries (DoF) in 1957, 2000, and 2010 infers that the population of fishing villages has almost tripled from 0.24 million in 1957 to 0.68 million in 2000[55], and 0.89 million in 2010[56]. It constitutes 1.1 percent of the total population of the state, and also higher than the aggregate growth rate of state's population.[55] Importantly, the growth rate of active fisher population during the period 1986 to 2000 is 7.97 percent.[55] In both the districts, more than 90 percent of the people depending on fishing are most backward, e.g. 96.06 percent in Nagapattinam and 97.67 percent in the Cuddalore district,[55] and there is lower literacy rate among the fishing communities as compared to the average literacy rate of Tamil Nadu state.

Due to low development scenario and lack of other opportunities, fishing remains as the major source of income for the coastal population. Further, the study

Table 6 Fish Quantity (tonne) in Cuddalore and Nagapattinam District

	Cuddalore		Nagapattinam	
Year	Fish Quantity (tonne)	Growth (%)	Fish Quantity (tonne)	Growth (%)
1998–99	3398 (3.06)	-	4150 (3.74)	-
1999-00	5316 (4.75)	56.44	4921 (4.39)	18.58
2001-02	9272 (8.16)	-	4393 (3.86)	-
2002-03	4299 (4.21)	-53.63	4343 (4.26)	-1.14
2003-04	6792 (8.79)	57.99	3416 (4.42)	-21.34
2004-05	6549 (8.49)	-3.58	3038 (3.94)	-11.07
2005-06	14631.19 (9.38)	123.41	5588.85 (3.58)	83.96
2006-07	14893.76 (9.3)	1.79	5700.63 (3.56)	2.00
2007-08	15206.37 (9.24)	2.10	5812.41 (3.53)	1.96
2009-10	15641.84 (9.31)	-	6433.01 (3.83)	-
CAGR (1998-2010) %	14.89	-	4.07	-

Figures in the parentheses indicate percentage figure; and CAGR ? Compound Annual Growth Rate
Source: Statistical Handbook of Tamil Nadu (different years)

villages except seven villages[i] have current fallows due to lack of fresh water, and absence of natural barrier like mangrove forests that led to intrusion of salt water into the agricultural land, particularly in the Cauvery delta of the Nagapattinam district. For these reasons the coastal people have been forced to mainly engage in fishing activities. It is observed that the dependency and extraction of fishing have increased sharply after the Indian Tsunami 2004 (see Table 6). Going by the primary source of information this could be attributed to the increase in numbers of boats that people own (mostly donated by international aid agencies after Tsunami year).

On the other hand, the consequences of climate change seem to have significant impact on fisheries in a variety of ways. For example, with steadily changing water temperature, precipitation and oceanographic variables, such as wind velocity, wave action and sea level rise can severely affect the occurrence of fish population, which directly has an impact on the people whose livelihoods depend on fishing.[8] Further, the potential declines in mangrove forests[j], changes in sediment and coastal structure, and industrial pollutant, especially in the Cuddalore district, loading from river combined with land reclamation for agriculture or overexploitation could also have an impact on fisheries by reducing or degrading critical coastal habitats.[8]

It is observed that on one hand, there is increasing number of people depending on fishing for their basic livelihoods, and on the other hand, there is a declining trend of fish population due to possible effects of climate change along with other socio-economic and environmental factors8. Both the trends contribute to the overall decline in fish population. Therefore, it affects the livelihoods of people

[i]Data is being collected from respective village administrative officer (VAO).
[j]In the Pichavaram mangrove forests, the remote sensing maps show that there was a loss of 471 ha from 1970–91 and a gain of 531 ha in 201157.

dependent on fishing activities, particularly marginal and small fishermen are affected badly as they do not have access to use sophisticated technologies like the large fishermen. There is not only declining trend in fish availability but also there is a trend in reduction in number of days that the fishermen are engaged in fishing activities as compared to the earlier years, e.g. currently average number of fishing days is 16.08 days/ month, whereas earlier it was 20.08 days/ month.

Apart from this, due to contamination of river water, there is a substantial decreasing backwater fish population. It has additional impacts on the livelihoods of marginal and small fishermen, especially during the ban period[k] as there is no other income opportunity. For instance, some fish species, namely as Sudhumbu, navarai, sura, veral and kanavai, have completely disappeared. Importantly, until two decades ago, shrimp[l] catch in the backwaters was abundantly available for export, whereas it has drastically declined now. In the study villages, 90 percent of the fisher respondents are either illiterate or educated up to primary, and this has a bearing on their ability to shift to other livelihood opportunities. Further, nearly 80 percent of the respondents are depending on the informal sources for availing credit, especially money lenders and fish merchants. In doing so, either they are paying higher rate of interest on loan or forced to sell fish to the middle men who provide access to loan at lower price. Such causes in addition to decreasing fishing population have increased the vulnerability of the coastal fishermen. Furthermore, there is a possibility that the vulnerability could be exacerbated in the coming years due to the change in climatic trends.

4.3. *Sensitivity of Farming Community*

In the villages situated 6-20 km from the shoreline in the both Cuddalore and Nagapattinam districts, agriculture is the main source of livelihoods. For instance, as per Census (2001), 65.27 percent of people in Cuddalore and 64.92 percent of people in Nagapattinam district are depending on agriculture for their income.

The coastal belt of Cuddalore and Nagapattinam districts is abound with green rice fields, coconut groves, mango, and banana plantations along with other vegetations. In general, there are two seasons (Season 1: June to December including both SWM and NEM, and Season 2: January to May) for growing different types of crops. Rice is the staple crop of this region, cultivated in two distinct cropping patterns. In the first pattern, the paddy seeds known as 'Kuruvai' with duration of 110 to 120 days from June-July to September-October. This is followed by cultivation of paddy seeds called 'Thaladi', having a duration of 135

[k]The government has imposed fishing ban every year from 2001 onwards, during the fish breeding season for a period of 45 days, i.e. from 15th April to 29th May. In the month of October to December (NEM period), fishermen never go to sea to catch fish due to high probability of occurrence of cyclonic storms during this period.

[l]The area under shrimp culture is 927 ha (43.69 percent of Tamil Nadu state) in the Nagapattinam district and 325 ha (15.32 percent of Tamil Nadu state) in the Cuddalore district)55.

days from September-October to January-February. In the second pattern, long duration paddy crop, e.g. 'Samba rice' is sown, which has a duration of 5 to 6 months from August to January-February. The choice of paddy seeds depends on the soil quality and geography of land and climatic condition of a particular year. During season 2, farmers generally cultivate groundnut and black gram. The major sources of irrigation in the study districts are rivers, few rain-fed tanks and wells. Mostly, these tanks and wells are found mostly in the up-land region. The soil type is mainly clayey and sandy clay.

Table 7 shows area and yield rate of paddy in the both Cuddalore and Nagapattinam districts. In the Cuddalore district, there is a declining trend of area under paddy cultivation, e.g. CAGR (%) is -1.12 percent. In contrast, it is marginally increasing in the Nagapattinam district (e.g. 0.53 percent). The CAGR (%) of yield rate is increasing in both the districts, and in particular, the rate of increase is high in the Cuddalore district in comparison to the Nagapattinam district. During the period of 1996 to 2008, the annual growth rate has been affected four times negatively in Cuddalore district and six times negatively in the Nagapattinam district (see Table 7); this may have happened due to erratic climatic condition in that particular year. It is observed that three times annual growth rate of yield has declined more than 50 percent in the Nagapattinam district, e.g. 2002–03, 2004–05 (Indian Tsunami year) and 2007–08 (see Table 7). Among the two districts, the probability of losing crops is higher in the Nagapattinam district as compared to the Cuddalore district.

In both the districts, around 90 percent of the farmers are marginal and small, e.g. 91.22 percent in the Cuddalore district and 90.78 percent in the Nagapattinam district (see Table 8). It is inferred that most of the farmers are economically poor and have fewer resources to cope with any kind of the climatic shocks.

Based on the in-depth interviews and FGDs, it is found that the original seasons

Table 7 Area and Yield Rate of Paddy in both Cuddalore and Nagapattinam District

	Cuddalore				Nagapattinam			
Year	Area (in ha)	Growth (%)	Yield (kg/ha)	Growth (%)	Area (in ha)	Growth (%)	Yield (kg/ha)	Growth (%)
1996-97	116400	-	1878	-	145355	-	1648	-
1997-98	116600	0.17	3071	63.53	157000	8.01	1717	4.19
1998-99	121300	4.03	3447	12.24	159200	1.40	3464	101.75
1999-00	127843	5.39	3500	1.54	162381	2.00	3190	-7.91
2000-01	114320	-10.58	3671	4.89	167320	3.04	3272	2.57
2001-02	108375	-5.20	3720	1.33	168265	0.56	2540	-22.37
2002-03	102340	-5.57	2753	-25.99	137720	-18.15	1158	-54.41
2003-04	104162	1.78	3050	10.79	136039	-1.22	1910	64.94
2004-05	115000	10.40	2755	-9.67	153000	12.47	919	-51.88
2005-06	114000	-0.87	1910	-30.67	158000	3.27	864	-5.98
2006-07	105440	-7.51	3721	94.82	165714	4.88	3805	340.39
2007-08	102798	-2.51	3260	-12.39	154040	-7.04	1878	-50.64
CAGR:1996-2008 (%)	-1.12		5.14		0.53		1.19	

Source: Statistical Handbook of Tamil Nadu (different years)

Table 8 Operational Holding of Land

Size Class	Cuddalore (2000-01)			Nagapattinam (2000–01)			Tamil Nadu (2000–01)		
	No.	Area (Ha)	Mean	No.	Area (Ha)	Mean	No.	Area (Ha)	Mean
Marginal (< 1 ha)	230721 (77.47)	83013.21 (34.69)	0.36	134764 (74.77)	53089.1 (34.21)	0.39	5845962 (74.39)	2158755 (30.97)	0.37
Small (1-2 ha)	40962 (13.75)	57052.07 (23.84)	1.39	28859 (16.01)	40286.6 (25.96)	1.4	1226193 (15.6)	1711874 (24.56)	1.40
Semi-Medium (2-4 ha)	18816	50856.6	2.7	12330	33383.4	2.71	570716	1551135	2.72
Medium (4-10 ha)	6626 (2.22)	37452.77 15.65	5.65	3860 (2.14)	21452.6 (13.82)	5.56	192634 (2.45)	1094303 (15.7)	5.68
Large (> 10 ha)	711	10902.65	15.33	425	6989.37	16.45	23382	455449	19.48
Total	297836 (100)	239277.3	0.8	180238	155201	0.86	7858887	6971516	0.89
Ginni Coefficient		0.471			0.453			0.49	

Note: the figures in the parentheses indicate percentage figure
Source:http://www.indiastat.com/table/agriculture/2/agriculturallandholdings/153/436950/data.aspx; downloaded on 3rd August, 2011.

of 'Kuruvai' and 'samba' have disappeared. In addition, the farmers in both the districts have perceived yield decline up to 20 percent, especially rice in the recent years in comparison to the past 15 years due to different types of the events associated with the climate change. For instance, in Thennampattinam village of Nagapattinam district those farmers who use to get a yield of 4.5-5 tonnes of rice/ ha are now getting 2.5-3 tonnes/ ha. Sometimes farmers loose crops because of untimely rainfall during the critical stages of the crop life. The recent study by Geethalakshmi *et al.*[58] indicate that the productivity of rice crop declines by 41 percent for 40C increase in temperature in the Cauvery basin of Tamil Nadu; the Nagapattinam district falls under the Cauvery basin.

Further, decreasing trend is observed in the production of rice and net area sown (NSA) over the years with increase in mean of maximum temperature and an erratic trend of rainfall. More than 90 percent of farmers are depending on both formal and informal source of borrowing. The small and marginal farmers, particularly are depending on the informal sources. Besides this, a few farmers have gone for agricultural insurance. The agricultural insurance has not gained importance largely due to lack of money and delay in reimbursement of insured amount. The poor economic condition coupled with low level of education have exacerbated the vulnerability of the farmers in this region. There are also other barriers for crop production in this region like (i) increased input costs, (ii) lack of minimum support price (MSP) for all agricultural product except paddy, (iii) lack of formal markets to sell agricultural product, (iv) paucity of agricultural labour due to out-migration[m], and (v) Lack of crop insurance.

[m]Some studies also asserted that out that out-migration is linked to climate change.[60]

Table 9 Adaptation Measures in Agriculture and Fishery sectors

Adaptation Strategies	Adaptation Components	Expected Outcome	Current Trend	Constraints
Farm Management and Technology	Crop diversification: shifting from paddy to groundnut	Minimize expected loss	Good	Lack of information, credit and other inputs
	Mixed paddy cropping: sowing suitable paddy crops based on the geography of land and soil quality. For example, in low-land areas farmers grow water tolerant seeds as there is high probability of water logging, whereas they prefer to grow short-term and rain-fed crops in up-land areas.	Minimize expected loss	Good	Non-availability of HYV paddy seeds, and in particular year, they lose traditional paddy seeds due to cyclonic storm that led to loss of paddy crops
	Shifting to salt/flood/drought tolerant variety of paddy seeds[o]	Minimize expected loss	Fair	Soil type and poor water harvesting measures
	Shifting to short duration crop varieties	Increase in yield	Average	Non-availability of paddy seeds and suitable share-cropping land
	Adjusting dates of cropping calendar/ sowing dates	Effective utilization of water	Average (without any scientific inputs)	Lack of information on monsoon and right agronomic practices, and lack of irrigation facility
	Construction of small check dams and rain water harvesting	Increasing water availability and reduced exploitation of groundwater	Poor	Lack of institutional funding and policy measures
	Modern technology: use of tractor and power tiller	Increasing production capacity	Average	Low accessibility due to lack of credit
	Application of Fertilizer, especially gypsum	Land reclamation	Average	Lack of funds, knowledge and extension inputs

Contd.

Note: [o]After the 2004 Indian Tsunami, it was observed that traditional rice varieties had survived with saline water intrusion and logging, e.g. Kuzhividichan, Kalurundai, Surakuruvai, Vellakudavazhai and Kachakambalam. Therefore, the local farmers are keen on cultivating such varieties of crops.

Table 9 *Contd.*

Adaptation Strategies	Adaptation Components	Expected Outcome	Current Trend	Constraints
Fishing Management and Technology	GPS eco sound[p]	Increase in quantity of fish catch	Fair	Possible only with big boats and only used by progressive fishermen
	Deep sea fishing	Increase in quantity of fish catch	Poor	Possible only with big boats
	Ban period for fishing	To increase fish population To avoid expected loss during rough season	Very Good	Inadequate compensation for lean period, and lack of other income opportunity
	Use of common resource pool and imposing common restrictions on fishing activities	Increase in profit	Fair	Lack of co-operation and mutual understanding
Farm/ Fishing Financial Management	Institutional Credit (e.g. Commercial Bank, Agricultural Co-operative Society, and Grameen Bank etc)	Income & Consumption smoothing: withstanding climatic shocks	Fair	Lack of information, cumbersome procedure to avail loans, and high percentage of marginal and small farmers
	Non-Institutional Credit (e.g. Money Lender, Land Owner, Fish Merchant, Micro-credit, SHGs etc)	Income & Consumption smoothing: withstanding climatic shocks	Very Good	High interest rate
	Crop Insurance (weather based insurance and rainfall insurance), and Agricultural Credit Insurance	Recovery of loss in income due to climatic events	Fair	Lack of information, and bureaucratic procedures involved in getting back the insurance money[q], and lack of right process to estimate crop loss[r].

Contd.

Note: [p] In order to handle the declining of fish stock, GPS eco sound technique has been used in big boats to identify the location of fish stock.
[q] A large number of respondents told that probability of getting back insurance money is very low.
[r] At present, the insurance company has estimated crop loss with following either area based approach or meteorological data due to lack of long-term information to fix premium rate.

Table 9 *Contd.*

Adaptation Strategies	Adaptation Components	Expected Outcome	Current Trend	Constraints
Diversification on and beyond Farm/ Fishing	Seasonal migration of head of the household and other members	Reduction in risks associated with climate change, and increase in family income	Average	Rudimentary education that acts as a hurdle for acquiring new skills
	Livestock rearing	Increase in family income and distress selling of livestock	Fair	Lack of credit and information from extension services on good local breeds
	Educating children	Reduction in expected future risks	Average	Poor economic condition of the family
	Participation in Self-Help Groups (SHGs)	Protection against money lender and availing loan during lean period to smooth consumption	Average	Low level of education making it difficult to opt for the right interventions/ business strategies
Government Assistance	Building schools, increasing teachers, free education, mid-day meal scheme[s]	Reduction in mal-nutrition, and providing alternative income opportunity	Very Good	Lack of infrastructure and quality education
	Generating job through MGNREGS, especially during lean period	Reduction in level of risks associated with the climatic shocks/ events	Very Good	Un-availability of labourers for agricultural operation
	Ex-post compensation, e.g. grant per acre of land.	Reduction in ex-post loss and help to smooth consumption	Average	Unfair claims
	Increasing beneficiaries of agricultural crop loans	Protection against money lender, and availing loan waiver during the shock period	Average	Lack of information, and high percentage of share cropping practioners.
	Subsidies for agricultural inputs	Reduction in the cost of cultivation, and increase yield	Average	Lack of information

Contd.

Note: [s]To encourage students of fishing community, the government is providing cash award and merit certificate to boys and girls from the community who have secured top rank in 10th and +2 standard examination at district and state level.

Table 9 *Contd.*

Adaptation Strategies	Adaptation Components	Expected Outcome	Current Trend	Constraints
	Irrigation facility	Reduction in dependency on rainfall and risks associated with the climatic shocks	Fair	Lack of investment
	Free electricity for agriculture	Reduction in cost of cultivation and increase in yield through irrigation	Very good	Over exploitation of ground water
	PDS (public distribution system)	Consumption smoothing	Very Good	Declining interest in agriculture and other income generation activities
	Old-age, Widow and Disability Pension scheme	Provide livelihood for destitute	Very Good	Less Compensation
	Communication Facility	Reduction in competition of agricultural job in rural villages	Very Good	Requirement for more investment
	Information associated with climate	Help farmers to take suitable decision in farming and reduce expected loss	Poor	Need right information at the right time and need for good forecasts
	National saving-cum-relief scheme for marine fishermen[t]	Reduction in risks during lean period	Very Good	Lack of Information
	Government financial assistance during Ban period[u]	Consumption smoothing	Very Good	Lack of Information

Contd.

Note: [t]To meet economic needs during rough season, the fisherman/ fisherwoman contributes Rs. 600/- (i.e. Rs. 70/- per month as his share for the first eight months and Rs. 40/- for the nine month. The contribution is matched with total amount of Rs. 1200/- by the Central and State Governments equally (i.e. Rs. 600/- each). Thus, a sum of Rs. 1800/- including the fisherman/ fisherwoman contribution is disbursed to the beneficiaries during the three lean months.[56]

[u]During the ban period, government has been providing financial assistance of Rs. 2000/- to people engaged in marine fishing from the year 2011-12, and earlier it was Rs. 1000/- 56.

Table 9 *Contd.*

Adaptation Strategies	Adaptation Components	Expected Outcome	Current Trend	Constraints
	Fishermen Accident Insurance Scheme[v]	Reduction of ex-post risks and consumption smoothing	Very Good	Lack of information
	Motorisation of traditional boats[w]	Increasing intensity of fishing	Average	Lack of Information
	Reimbursement of Central Excise duty on high speed diesel (HSD)[x]	Reduction in operational cost & income smoothing	Average	Lack of Information, and use of traditional boats by majority of the fishermen
	Increasing Awareness and conservation of Mangrove forests	Reduction in impact cost of extreme events and increase in fish population	Good	Lack of information and awareness
knowledge management, networks and governance	Social networks: Village committees, especially found in fishing village[y]	Consumption smoothing	Very Good	Local politics

Note: [v]Since there is risk and uncertainty associated with fishing, most of the fisherman avail insurance to compensate in the case of occurring any accident. In case of death/ permanent disablement, the fisherman will be given Rs. 1,00,000/- and an amount of Rs. 50,000/- will be given for partial disablement.[56]

[w]Under this scheme the fishermen will be provides with 50 percent subsidy of the unit cost with a ceiling limit of Rs. 30,000/- per Out Board Motor (OBM).[56]

[x]The subsidy will be limited to Rs.3/- per liter of HSD oil with a ceiling of 500 liters per boat, per month during active fishing months.[56]

[y]After the shock, the village head will borrow a bulk amount of money from the rich people in the village and distribute it among the needed fisherman. The village head is the responsible to collect and also pay back.

Source: Field survey

4.4. *Livelihood Based Adaptation*

This section summarizes the different adaptive measures practiced by both the farmers and fishermen to manage risks against climate variability and shocks along with the assessment of the respective practices and their constraints. The existing adaptation measures has been categorized into five based on the model of Below *et al*.:[59] (1) farm management and technology/ fishing management and technologies, (2) farm financial management, (3) diversification on and beyond the farm, (4) government assistance and (5) knowledge management, networks and governance.

5. Conclusions

Majority of the people, especially in developing nations are depending on climate sensitive sectors like agriculture and fishing for their basic livelihood. Adaptation at the local level provides an opportunity to manage climate risks and reduce vulnerability. The present study recognizes the context of vulnerability and assesses the effectiveness of adaptation options and provides a simplistic framework to understand the nexus between locally driven livelihoods based vulnerabilities and the adaptation outcomes for both agriculture and fishing communities in the coastal areas of Cuddalore and Nagapattinam districts. The climate data analyses have indicated changes in climate vulnerability due to extreme events have significant impacts on the local livelihoods. The study has implication for sustainable adaptation calling for strengthening local level actions.

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